Chapter 9 - Ecological Research at the Idaho National Environmental Research Park

Chapter Highlights

The Idaho National Engineering and Environmental Laboratory (INEEL) was designated as a National Environmental Research Park (NERP) in 1975. The NERP program was established in response to recommendations from citizens, scientists, and members of Congress to set aside land for ecosystem preservation and study. In many cases, these protected lands became the last remaining refuges of what were once extensive natural ecosystems. The NERPs provide rich environments for training researchers and introducing the public to ecological sciences. NERPs have been used to educate grade school and high school students and the general public about ecosystem interactions at U.S. Department of Energy (DOE) sites; train graduate and undergraduate students in research related to site-specific, regional, national, and global issues; and promote collaboration and coordination among local, regional, and national public organizations, schools, universities, and federal and state agencies.

Ecological research at the INEEL began in 1950 with the establishment of the long-term vegetation transect. This is perhaps DOE's oldest ecological data set and one of the oldest vegetation data sets in the West. Ecological research on the NERPs is leading to better land use planning, identifying sensitive areas on DOE sites so that restoration and other activities are compatible with ecosystem protection and management, and increasing contributions to ecological science in general.

The following ecological research activities took place at the Idaho NERP during 2003:

- Monitoring Amphibian and Reptile Populations on the INEEL;
- The Effect of Landscape Change on the Life History of Western Rattlesnakes;
- Factors that Influence the Road Mortality of Snakes on the Eastern Snake River Plain;
- Behavior, Dispersal, and Survival of Captive-Raised Idaho Pygmy Rabbits Released onto the INEEL in Idaho;
- Use of Genetic Markers as a Screening Tool for Ecological Risk Assessment at the INEEL: Microsatellite Mutation Rate of Burrowing Mammals;

- Crested Wheatgrass Rates of Spread into Native Sagebrush Steppe in Eastern Idaho;
- Experimental Remote Sensing of Vegetation on the INEEL;
- Natural and Assisted Recovery of Sagebrush in Idaho's Big Desert;
- Sagebrush Demography on the INEEL;
- Development of an Integrated Watershed Information Management Tool for Long-term Facilities Stewardship at the INEEL;
- Ecological Impacts of Irrigating Native Vegetation with Treated Sewage Wastewater;
- The Protective Cap/Biobarrier Experiment;
- Assessing the Effects of Soil-forming Processes on Surface Caps; and
- Coupled Effects of Biointrusion and Precipitation on Soil Caps.

9. ECOLOGICAL RESEARCH AT THE IDAHO NATIONAL ENVIRONMENTAL RESEARCH PARK

The Idaho National Engineering and Environmental Laboratory (INEEL) was designated as a National Environmental Research Park (NERP) in 1975. The NERP program was established in response to recommendations from citizens, scientists and members of Congress to set aside land for ecosystem preservation and study. This has been one of the few formal efforts to protect land on a national scale for research and education. In many cases, these protected lands became the last remaining refuges of what were once extensive natural ecosystems.

There are five basic objectives guiding activities on the NERPs. They are to:

- Develop methods for assessing and documenting the environmental consequences of human actions related to energy development.
- Develop methods for predicting the environmental consequences of ongoing and proposed energy development.
- Explore methods for eliminating or minimizing predicted adverse effects from various energy development activities on the environment.
- Train people in ecological and environmental sciences.
- Use the NERPs for educating the public on environmental and ecological issues.

The NERPs provide rich environments for training researchers and introducing the public to the ecological sciences. They have been used to educate grade school and high school students and the general public about ecosystem interactions at U.S. Department of Energy (DOE) sites; train graduate and undergraduate students in research related to site-specific, regional, national, and global issues; and promote collaboration and coordination among local, regional, and national public organizations, schools, universities, and federal and state agencies.

Establishment of NERPs was not the beginning of ecological research at federal laboratories. Ecological research at the INEEL began in 1950 with the establishment of the long-term vegetation transect study. This is perhaps DOE's oldest ecological data set and one of the oldest vegetation data sets in the West. Other long-term studies conducted on the Idaho NERP include the reptile monitoring study initiated in 1989, which is the longest continuous study of its kind in the world; as well as the protective cap biobarrier experiment initiated in 1993, which evaluates the long-term performance of evapotranspiration caps and biological intrusion barriers.

Ecological research on the NERPs is leading to better land-use planning, identifying of sensitive areas on DOE sites so that restoration and other activities are compatible with ecosystem protection and management, and increasing contributions to ecological science in general.

The Idaho NERP provides a coordinating structure for ecological research and information exchange at the INEEL. The Idaho NERP facilitates ecological research on the INEEL by attracting new researchers, providing background data to support new research project development, and providing logistical support for assisting researcher access to the INEEL. The Idaho NERP provides infrastructure support to ecological researchers through the Experimental Field Station and museum reference collections. The Idaho NERP tries to foster cooperation and research integration by encouraging researchers using the INEEL to collaborate, develop interdisciplinary teams to address more complex problems, and encourage data sharing, and by leveraging funding across projects to provide more efficient use of resources. The Idaho NERP has begun to develop a centralized ecological database to provide an archive for ecological data and facilitate retrieval of data to support new research projects and land management decisions. The Idaho NERP can also be a point of synthesis for research results that integrates results from many projects and disciplines and provides analysis of ecosystem-level responses. The Idaho NERP also provides interpretation of research results to land and facility managers to support the *National Environmental Policy Act* (NEPA) process, natural resources management, radionuclide pathway analysis, and ecological risk assessment.

The following sections describe ecological research activities that took place at the Idaho NERP during 2003.

9.1 Monitoring Amphibian and Reptile Populations on the INEEL: Indicators of Environmental Health and Change

Investigators and Affiliations

Christopher L. Jenkins, Graduate Student, Herpetology Laboratory, Department of Biological Sciences, Idaho State University, Pocatello, ID

Charles R. Peterson, Professor, Herpetology Laboratory, Department of Biological Sciences, Idaho State University, Pocatello, ID

Funding Sources

U.S. Department of Energy Idaho Operations Office

Background

Many amphibian and reptile species have characteristics that make them sensitive environmental indicators. The main research goal is to provide indicators of environmental health and change by monitoring the distribution and population trends of amphibians and reptiles on the INEEL.

Information from this project is important to the DOE for several reasons: (1) as an indicator of environmental health and change; (2) for management of specific populations of sensitive species; (3) for meeting NEPA requirements regarding the siting of future developments; (4) for avoiding potentially dangerous snake-human interactions; and (5) for providing a basis for future research into the ecological importance of these species. Additionally, this project provides venomous snake safety training to INEEL employees and summer assistants. This training provides key information on how to avoid and treat bites from venomous snakes. It also helps workers place the relatively low risk of snakebite in perspective and fosters an appreciation of the ecological role of snakes on the INEEL. Finally, this project assists in the training and support of undergraduate and graduate students in environmental research.

Objectives

The overall goal of this project is to determine amphibian and reptile distribution on the INEEL and monitor populations in select areas. Specific objectives for 2003 included the following:

- Continue monitoring snake and lizard populations;
- Continue entering current herpetological information into a geographic information system (GIS) database;
- Provide herpetological expertise, as needed;.

- Provide snake safety workshops; and
- Provide educational opportunities for undergraduate and graduate students.

Accomplishments through 2003

Specific accomplishments for 2003 include the following:

- Continued monitoring efforts at three den sites allowed more accurate estimates of reptile abundances on the INEEL (Figure 9-1). These estimates will allow examination of population trends over time. Currently, the team is working on new ways to monitor the health of rattlesnake populations on the INEEL. It is believed that calculating condition indices may be an additional method for assessing population health in western rattlesnakes. Western rattlesnakes are relatively long lived, active for short periods of the year, and require multiple years of foraging to have one successful reproduction. Because of these factors, environmental characteristics such as habitat degradation or weather patterns could indirectly influence the condition indices by altering prey resources. For example, spatial variation in body condition may indicate spatial patterns of habitat degradation or weather (Figure 9-2). Trends in body condition over time may indicate how patterns in habitat or weather are changing temporally (Figure 9-3). Overall, the team is still evaluating how to incorporate these condition indices into the monitoring program; however, it is agreed that this information will be an effective complementary method for monitoring snake health.

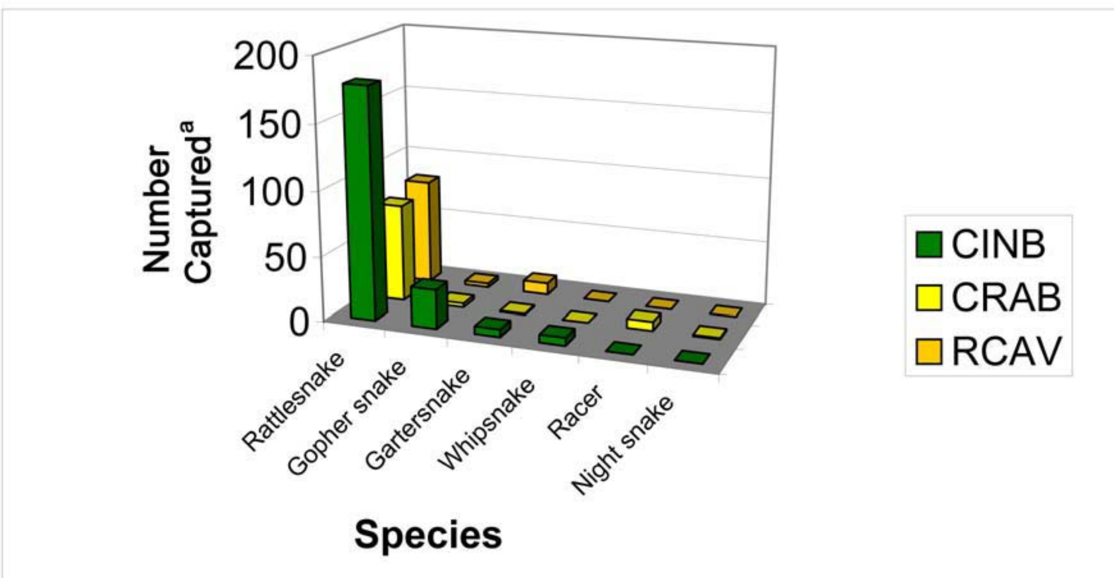

Figure 9-1. Abundance of snakes captured by species at three den complexes (Cinder Butte [CINB], Crater Butte [CRAB], and Rattlesnake Cave [RCAV]) during 2003 on the INEEL.

a. Including western rattlesnakes (Crotalus oreganos), gopher snakes (Pituophis catenifer), western terrestrial garter snakes (Thamnophis elegans), whipsnakes (Masticophis taeniatus), racers (Coluber constrictor), and night snakes (Hypsiglena torquata). In addition, 130 snakes were captured at other den locations on the INEEL.

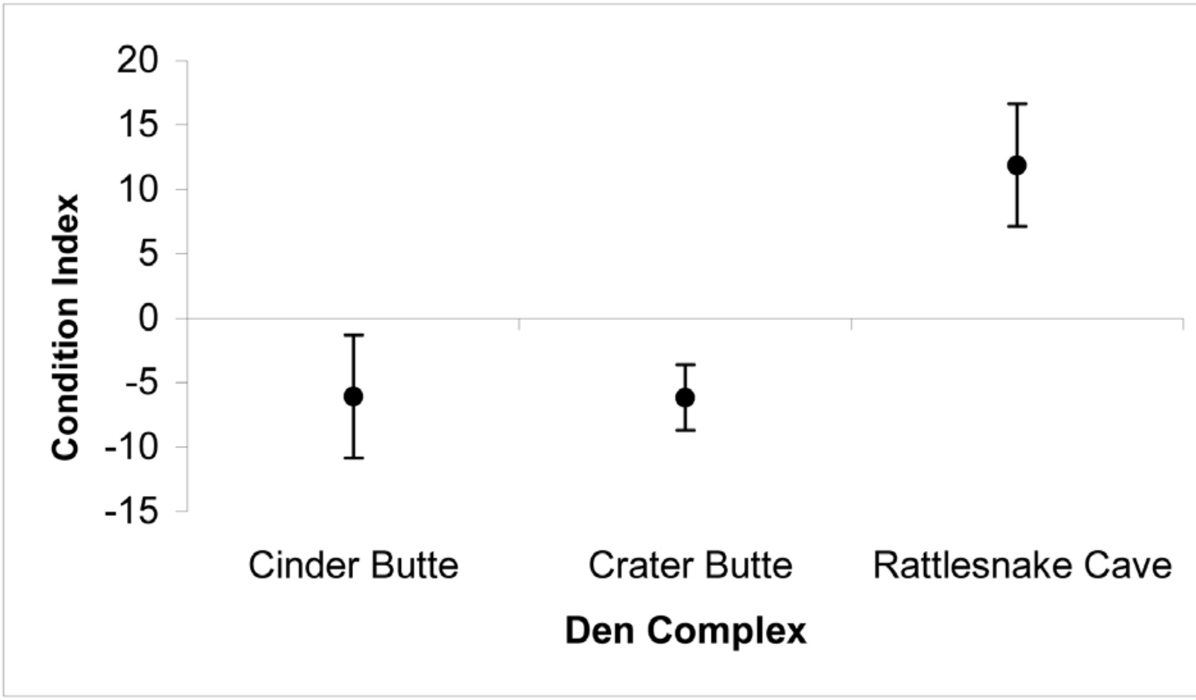

Figure 9-2. Average body condition of female western rattlesnakes by den complex on the INEEL. Error bars represent one standard error.

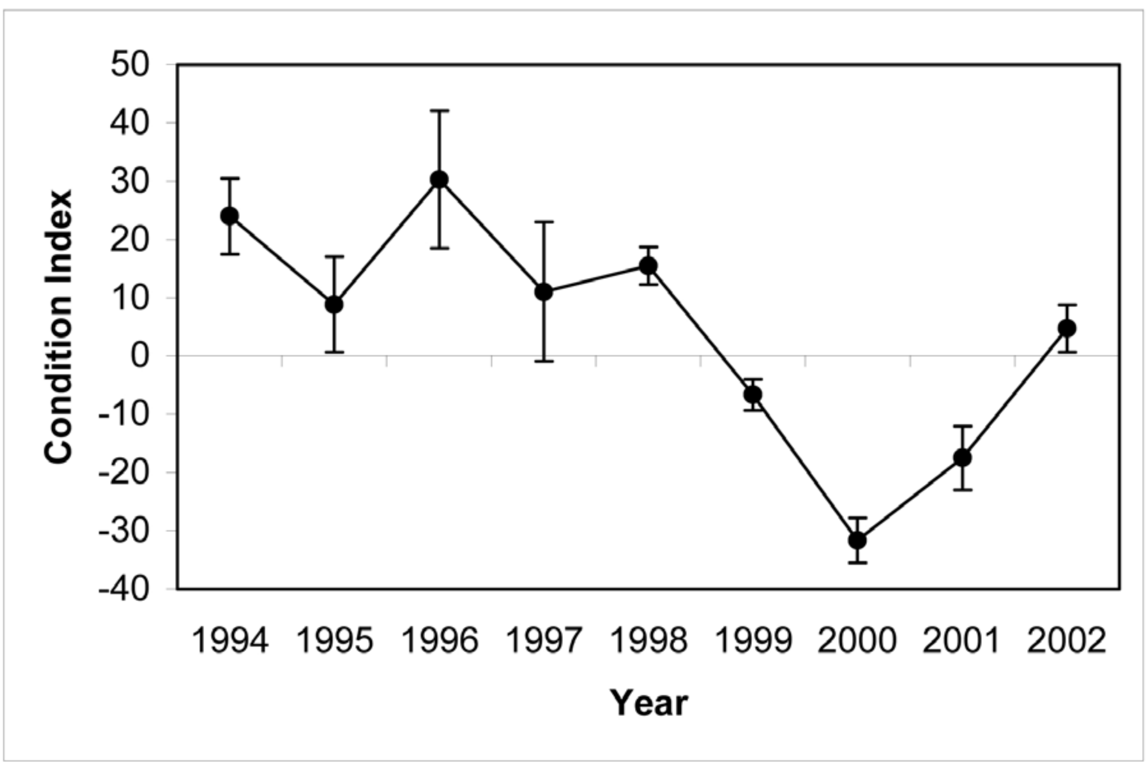

Figure 9-3. Average annual body condition of adult male rattlesnakes captured on the INEEL. Error bars represent one standard error.

- Updated the INEEL Herpetological database using the observations gained from the team's research.

- Provided herpetological expertise to numerous groups on the INEEL in 2003 including snake safety training sessions and field safety consultations.

Results

Important results this year included confirming the continued presence of leopard lizards *(Gambelia wislizenii)* at Circular Butte, continuing radiotelemetry studies, beginning small mammal trapping, and providing specific herpetological expertise to several groups on the INEEL.

- The number of marked snakes on the INEEL increased in 2003 to 3390, including all snakes PIT-tagged since 1994 and marking data collected at Cinder Butte from 1989 to 1994.

- Two observations of a leopard lizard *(Gambelia wislizenii)* were made at Circular Butte in 2003. Many western skinks *(Eumeces skiltonianus)* and sagebrush lizards *(Sceloporus graciosus)* were sited across the entire INEEL, and two short-horned lizards *(Phrynosoma douglassii)* were found close to the Rattlesnake Cave snake den location.

- The team did not observe breeding activity by spadefoot toads (*Scaphiopus intermontanus*) on the INEEL in 2003.

- As part of Chris Jenkins' Ph. D research, radiotelemetry work continued and small mammal trapping began in the southeastern portion of the INEEL to look at the effects of landscape characteristics on rattlesnake populations.

- Provided herpetological expertise in the form of presenting five snake safety training sessions and outreach to the public through programs for children both onsite and at the INEEL Science Expo. In addition, herpetological data for the site was disseminated, and conducted field safety consultations. The snake safety sessions have generated positive feedback from the employees, and many yield invitations for additional presentations, both on the INEEL and in local communities.

9.2 The Effect of Landscape Change on the Life History of Western Rattlesnakes *(Crotalus Oreganus)*.

Investigators and Affiliations

Christopher L. Jenkins , Graduate Student, Herpetology Laboratory, Department of Biological Sciences, Idaho State University, Pocatello, ID

Charles R. Peterson, Professor, Herpetology Laboratory, Department of Biological Sciences, Idaho State University, Pocatello, ID

Funding Sources

Idaho Department of Fish and Game

Bureau of Land Management

Idaho State University (ISU) Department of Biological Sciences

ISU Graduate Student Research Committee

INEEL - ISU Education Outreach Program

Background

This project was designed to assess the impact of landscape disturbance on western rattlesnakes by examining trophic interactions among habitat, small mammals, and snakes. The synergistic effect of livestock grazing, invasive plants and fire is changing sagebrush steppe ecosystems in the Upper Snake River Plain. It is hypothesized that this phenomenon is affecting the prey base of top-level predators in the system. The main research goal is to determine if changes in habitat are altering prey availability and subsequently life history characteristics of western rattlesnakes.

Information from this project is important to the DOE for several reasons: (1) as an indicator of how habitat change is influencing small mammal biomass; (2) as an indicator of how trophic interactions affect western rattlesnakes; (3) providing recommendations for the management and conservation of predators on the INEEL; (4) for utilizing a long-term mark recapture data set gathered by the ISU Herpetology Laboratory to further an understanding of community ecology on the INEEL; (5) assisting in the training of graduate and undergraduate students in environmental research.

Objectives

The overall goal of this project is to determine if current landscape patterns in habitat and prey on the INEEL are influencing rattlesnake life histories. Specific objectives for 2003 included the following:

- Quantifying spatial variation in rattlesnake life histories.
- Determining if rattlesnakes are selecting habitats with greater small-mammal biomass.
- Determining if disturbance to sagebrush steppe systems affects small-mammal biomass.

Accomplishments through 2003

Specific accomplishments for 2003 include the following:

- Found significant variation in life history characteristics among three den complexes on the INEEL (Table 9-1). More specifically, it was found that snakes at one den complex had life history characteristics that would indicate lower fitness.
- Found that small-mammal biomass was greater in snake core activity areas than in either migration corridors or random locations (Figure 9-4).
- Found that small-mammal biomass was highest in habitats characterized by relatively tall shrub cover, low grass cover, and high biological crust cover (Table 9-2).

Table 9-1. Life history characteristics calculated from western rattlesnakes captured between 1994-2002 at three den locations in southeastern Idaho.

	Den Location		
Life History Characteristics	**Cinder Butte**	**Crater Butte**	**Rattlesnake Cave**
Age at Maturity	4	6	**3**
Proportion of Females Pregnant	**0.25**	0.20	0.24
Number of Young	5.20 ± 0.32	4.40 ± 0.30	**5.92 ± 0.28**
Condition of Young[a]	-0.83 ± 0.14	-0.54 ± 0.15	**1.08 ± 0.22**
Female Body Condition	-6.08 ± 4.80	-6.16 ± 2.54	**11.88 ± 4.76**
Ecdysis (sheds/year)	1.66 ± 0.15	1.68 ± 0.18	**2.41 ± 0.23**
Growth (cm/year)	5.50 ± 0.96	3.60 ± 0.69	**5.95 ± 1.14**

a. Condition of young and adult females is calculated as the residual mass (i.e., residual values of the regression of mass to length).

b. Values in **bold** type represent the values presumed to be the most advantageous relative to the other den locations.

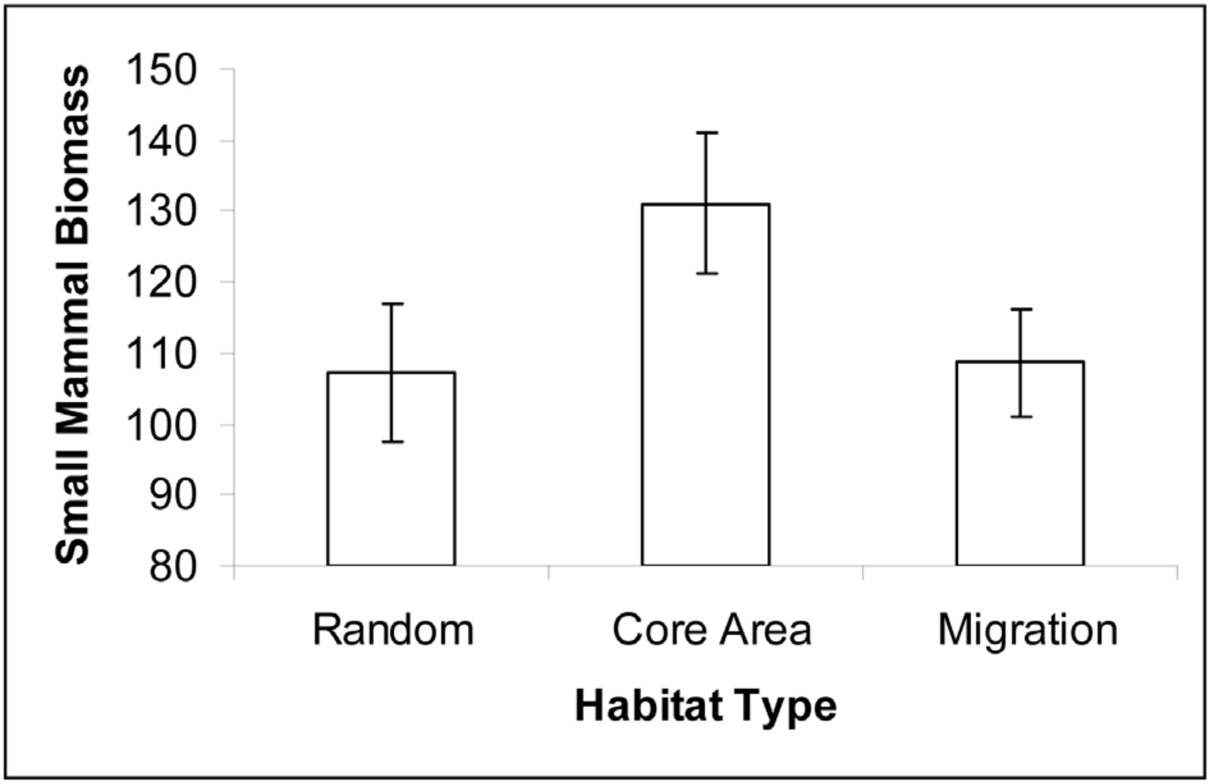

Figure 9-4. Average small-mammal biomass found in random areas, core areas of snake activity, and migration corridors used by snakes during summer 2003. Error bars represent one standard error.

Table 9-2. The best model for predicting small-mammal biomass in the study area, during the summer active period of snakes (May through September) 2003. The overall R^2 for the model was 0.26.

Variable	Coefficient	t-value	p-value
Intercept	1.70	6.78	<0.0001
Crust Cover	0.11	3.67	0.0003
Grass Cover	-0.20	-2.28	0.0236
Shrub Height	0.36	4.63	<0.0001

9.3 Factors Influencing the Road Mortality of Snakes on the Eastern Snake River Plain

Investigators and Affiliations

Denim M. Jochimsen, Graduate Student, Herpetology Laboratory, Department of Biological Sciences, Idaho State University, Pocatello, ID.

Charles R. Peterson, Professor, Herpetology Laboratory, Department of Biological Sciences, Idaho State University, Pocatello, ID.

Funding Sources

ISU Biological Sciences Department

ISU Graduate Student Research Committee

INEEL - ISU Education Outreach Program

ISU Biology Youth Research Program

Background

As significant features of most landscapes, roads generate a variety of ecological effects. Roads affect wildlife through the loss and fragmentation of habitat, disruption of movement patterns, and mortality from vehicular traffic (Forman and Alexander 1998). Many studies have documented traffic mortality on snakes (Bernardino and Dalrymple 1992; Rosen and Lowe 1994). Such mortality may severely reduce snake populations to a level where reproductive output cannot replace road-killed individuals (Rosen and Lowe 1994; Rudolph et al. 1999).

Unlike many factors (such as global warming and disease), the adverse effects of roads can be minimized, but the correct placement of mitigation efforts is critical. Ultimately, this research seeks to evaluate which landscape factors predict high-risk areas for snakes by developing a spatially-based model that relates observations of snake mortality on roads with attribute data gathered from these observations and landscape variables. This model should prove useful in developing priorities on a regional level concerning the mitigation of snake-highway conflicts.

Objectives

The objectives of this study include:

- Quantifying the road mortality of snakes on the Eastern Snake River Plain.
- Examining the variation of this mortality with respect to species, sex, age class, season, and traffic volume.
- Identifying and modeling the landscape factors that influence the spatial pattern of road mortality.

Accomplishments through 2003

- Successful completion of the 2003 field season including 258 total road observations of snakes along the survey route in more than 9350 km (5810 mi) driven
- Initiated spatial and statistical analyses of the data
- Presented general findings of this research at the Intermountain Herpetological Rendezvous in Logan, Utah
- Generated a poster publication to be used for subsequent presentation
- This survey method (road-cruising) will be integrated into future monitoring efforts of snake populations on the INEEL if funding is available.

Results

Road mortality of snakes was quantified by road cruising (driving slowly in a vehicle and recording all snakes observed on a road surface) a 170-km (105.5 mi) route from May through October of 2003. The survey route is located within the northeastern portion of the Snake River Plain and covers portions of U.S. Highways 20, 26, 20/26, and 22/33; Franklin Boulevard; and Lincoln Boulevard. Sampling consisted of 55 total trips along this route, and resulted in 9350 total kilometers (5810 mi) traveled over the 2003 field season.

A total of 258 snakes was observed on roads along the survey route and across the entire survey period; 93 percent of these animals were found dead on the road surface (kill rate of 0.028 individuals/km surveyed). Spatial visualization and analyses indicate that these observations are clustered along the survey route (Figure 9-5). The road mortality of four species belonging to families Colubridae and Viperidae was documented. However, the majority of observations belonged to two species, *Pituophis catenifer* (Great Basin gopher snake) and *Crotalus oreganus lutosus* (Great Basin rattlesnake). Gopher snakes were the most commonly observed snakes on roads comprising 74 percent of all road records, and rattlesnakes were observed more frequently than the remaining two species comprising 18 percent of all road records (Figure 9-6). Furthermore, more adult males of both species were observed dead on roads than any other sex or age class. Juvenile observations comprised only 28 percent of total gopher snakes, and 17 percent of total rattlesnake road mortality.

Monitoring data indicate that rattlesnakes are the most abundant species based on hand and drift fence captures at dens. In fact, rattlesnakes made up 85 percent of captured snakes (n = 2459), with gopher snakes representing most of the remaining percentage of snakes (n = 372) over a 10-year sampling period. This raises an interesting question: are gopher snakes more susceptible to road mortality on the Eastern Snake River Plain? This species is a habitat generalist and is perhaps more vagile than rattlesnakes, indicating that individuals would encounter roads more often, exposing them to the risk of road mortality.

The road mortality of snakes in all months surveyed was documented and seasonal patterns were evident. The mean number of snakes observed per route while road cruising was highest

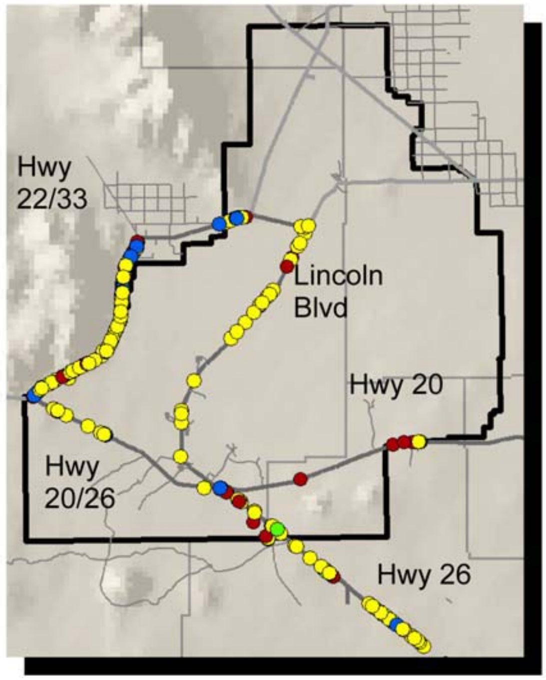

Figure 9-5. Spatial visualization of snake occurrences (n = 258) along the survey route from May to September 2003 generated in Arc GIS.

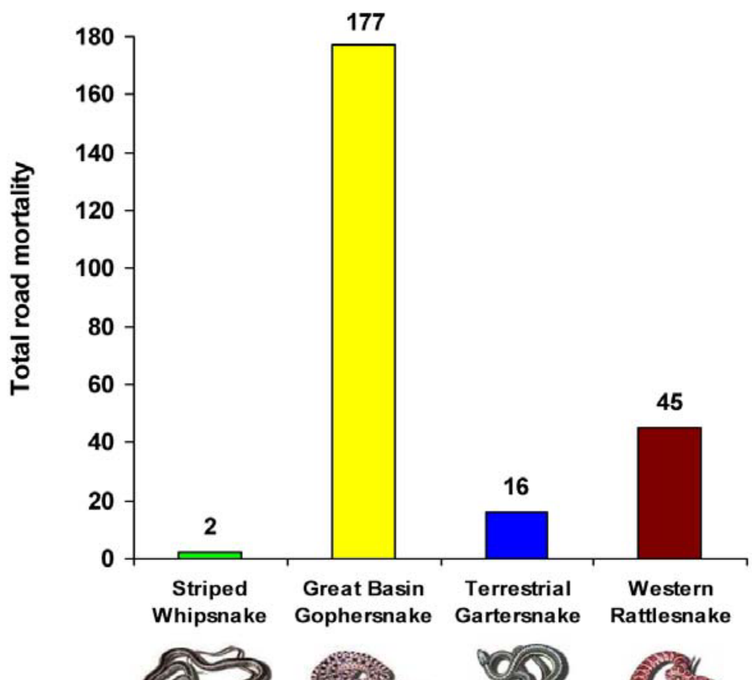

Figure 9-6. Road mortality accounted for 93 percent (n = 240) of all snake observations. (Although racers and night snakes occur within the study region in low densities, none were observed during road surveys. The colors correspond with the spatial map of locations [Figure 9-5]).

during the month of September (7.25), with secondary peaks in May (4.38) and June (4.76). The total number of sampling days without snake observations (10 total) was highest in late July and early August. These seasonal patterns are also evident with respect to sex and age. The road mortality of adult male gopher snakes was observed more often in May and June and of subadults during the month of September. Adult males were not observed on roads in either July or September. Observations of female road mortality did not exhibit a strong trend, but were observed less often during the summer months. These trends are different for rattlesnakes, with male observations exhibiting the highest mortality peaks in June and July, as well as a slightly lower peak in September. Subadult rattlesnakes were observed dead on roads only during the months of May through July, while females exhibited a bimodal peak of mortality with susceptibility to road mortality during June and September. The higher numbers of certain age and sex classes with respect to seasons indicates that individuals may be more susceptible to road mortality during specific movements. To be effective, methods designed to ameliorate the road mortality of snakes should coincide with these activity periods.

Finally, one road section (Highway 22/33 running N/S) had higher observations of snake roadkill than the others (Figure 9-5). In fact, 48 percent of mortality locations occurred along this 25.6 km (16 mi) stretch of highway. Although the location of many snake hibernacula are known across the INEEL, this particular area has not been extensively surveyed. To create a predictive model of landscape factors that influence road mortality, potential dens surrounding the route need to be located.

Plans for Continuation

- Efforts to search for new den sites along Highway 22/33 commenced in late April 2004 and will continue through early summer
- Road cruising (as a sampling method) will be added to current monitoring efforts of the snake populations on the site if funding is available
- Gather data on "available" locations along the route this June
- Multivariate statistical analysis including landscape and other variables collected onsite
- Development of a spatial model incorporating significant GIS variables to predict high-risk areas of road mortality.

9.4 Behavior, Dispersal, and Survival of Captive-Raised Idaho Pygmy Rabbits *(Brachylagus Idahoensis)* Released onto the INEEL in Idaho

Investigators and Affiliations

Robert Westra, Graduate Student, Department of Natural Resource Sciences, Washington State University, Pullman, WA

Rodney D. Sayler, Assoc. Professor, Department of Natural Resource Sciences, Washington State University, Pullman, WA

Lisa A. Shipley, Assoc. Professor, Department of Natural Resource Sciences, Washington State University, Pullman, WA

Funding Sources

Washington Department of Fish and Wildlife

Background

The pygmy rabbit *(Brachylagus idahoensis)* is the smallest rabbit in North America, a sagebrush foraging specialist, and one of only two North American rabbits to dig its own burrow. The long-isolated and genetically unique population of Columbia Basin pygmy rabbits located in eastern Washington State has declined precipitously to dangerously low levels and the U.S. Fish and Wildlife Service (USFWS) recently listed the Washington pygmy rabbits as an endangered population segment under the *Endangered Species Act*. Because little is known about successful captive-rearing and methods for restoring pygmy rabbits back into vacant natural habitats, reintroduction techniques in southeastern Idaho are being tested to develop protocols for the eventual restoration of endangered pygmy rabbits in Washington State. Idaho pygmy rabbits are propagated in captivity at Washington State University (WSU) and elsewhere and released into the wild in southeastern Idaho. The Idaho Fish and Game Department supervises these releases to determine whether selected captive rearing and release methods influence the behavior, dispersal, and survival of pygmy rabbits reintroduced into suitable sagebrush habitat.

Objectives

- Develop techniques to enhance the survival of captive-bred Idaho pygmy rabbits released into natural habitats for the purpose of establishing new local populations of pygmy rabbits.
- Test the effects of captive-rearing and release methods on the resulting behavior, dispersal, and survival of reintroduced pygmy rabbits.
- Develop recommended protocols for restoring pygmy rabbits in areas of vacant, suitable sagebrush habitat, and model the numbers of captive-bred animals and survival rates needed to establish new local breeding populations.

Accomplishments through 2003

A total of 13 rabbits were released in August and seven in September 2002 at the INEEL. In July 2003, an additional seven rabbits were released. These animals were raised in captivity at WSU, fitted with radio collars weighing <2 percent of body weight, and released into temporary, weld-wire containment pens. The temporary pens surrounded the two openings of 3.0 to 4.5 meter (m) (10 to 15 foot [ft]) long plastic drainage tube burrows dug into the soil about 0.75 to 1.0 m (2.5 to 3.5 ft) deep in the center. The plastic-tubing burrows were used to partially replicate a natural pygmy rabbit burrow system and provide both thermal buffering and some protection against digging predators. Another goal of the artificial burrow system was to reduce premature dispersal of rabbits away from the release site selected in good sagebrush habitat. Rabbits released in 2003 were monitored almost daily to record behavior, dispersal and habitat use, and survival from July through early September.

Results

All released rabbits readily adapted to the small, temporary holding cages surrounding their burrow openings and continued normal feeding on provided foods (i.e., sagebrush tips, spinach, lettuce, pellet food). All containment pens were removed from the burrows by the fourth day, allowing free movement and dispersal of the animals.

Rabbits moved an average of 54.1 m (177.5 ft) from their initial release burrow during their first week after soft release. Most rabbits remained fairly localized on the release site. Mean movement distances did not vary significantly among the first, second, or third week after soft release. Most captive-bred, dispersing animals selected an appropriate habitat consisting of relatively tall, dense big sagebrush with relatively good grass and forb availability. Released animals appeared to adapt to natural local forage quickly and appeared to use a high proportion of grass and forbs until colder weather in fall and winter, which prompted greater use of sagebrush.

Predation was the main source of mortality for released pygmy rabbits. Of the 44 released animals, approximately 26 percent were censured from the study (primarily because radio signals were lost and because of one collar malfunction), 42 percent were lost to predators, 19 percent were lost to unknown mortality factors, and 12 percent were alive at the end of the project. Eighteen of the 27 documented mortalities were caused by predators. Four mortalities were caused by raptors; northern harriers *(Circus cyaneus)* were directly observed in two predation events. Twelve animals were killed by long-tailed weasels *(Mustela frenata)* and two were confirmed coyote *(Canis latrans)* kills.

Survival - Total survivorship for the release population was 0.138 (S.E + 0.085). This survivorship translates to an annual survival rate of 32 percent. Age and sex did not significantly influence survival, although the ability to detect such differences was limited. Males and females had similar survivorship; however, females experienced a higher mean survival time (175.7 days) than males (83.6 days). Annual survival rate was 18 percent for males and 30 percent for females.

Survival varied significantly among seasons (i.e., release groups). The annual survival rate was 0 percent for July, 24 percent for August, 32 percent for September, and 18 percent for February. However, the February release group had 50 percent of the rabbits released from the soft-release cages survive until the breeding season.

Survival quantiles for the released rabbits show a 76 percent survivorship for the first six days post soft-release, declining to 28 percent by day 95. Survivorship did not drop below 25 percent until day 260.

Reproduction of Reintroduced Pygmy Rabbits - In June 2003, it was confirmed that at least one of the two surviving females released in 2002 had given birth on the INEEL release site. One of the females was observed with at least one pygmy rabbit kit associating closely with her around her burrow site. The first observation was made by biologist, Sue Vilord, and this sighting was independently confirmed later by the graduate student working on the release project, Robert Westra.

Plans for Continuation

This study on the INEEL has been a major research component of the recovery program for the endangered Columbia Basin pygmy rabbit in Washington, but will also provide valuable information in the event that local reintroductions are warranted for Idaho pygmy rabbits. Currently, two theses containing five technical papers are being completed at WSU for submission to scientific journals. These detailed technical reports will be available in 2004. Contact the investigators for more information.

9.5 Use of Genetic Markers as a Screening Tool for Ecological Risk Assessment at the Idaho National Engineering and Environmental Laboratory: Microsatellite Mutation Rate of Burrowing Mammals

Investigators and Affiliations

Angela Stormberg, Principal Scientist, Idaho National Engineering and Environmental Laboratory, Idaho Falls, ID

Joseph Cook, Department of Biological Sciences, Idaho State University, Pocatello, ID

Funding Sources

Laboratory Directed Research and Development (LDRD)

Background

The purpose of this research was to explore the utility of molecular genetic techniques as screening tools for evaluating the risk to natural populations from contaminant exposure. These tools can be used to help evaluate the need for site remediation. If remediation is implemented, genetic characterization of populations can provide insight on the effectiveness of the remediation through long-term monitoring.

This was a three-year study to determine if radiological contamination affects the genome of deer mice *(Peromyscus maniculatus)*. Radiological and genetic analysis were performed on deer mice collected outside the *Comprehensive Environmental Response, Compensation, and Liability Act* (CERCLA) sites of the stationary low-power reactor number 1 (SL-1) and the Radioactive Waste Management Complex (RWMC), and two control sites (Burn and Atomic City).

Radiological and hazardous wastes have been disposed of at the INEEL since 1952. Escape of radionuclides and hazardous constituents from uncontained wastes, deterioration of waste containers, and waste disposal practices have resulted in contamination of the subsurface soils at the INEEL's Subsurface Disposal Area (SDA) and at other facilities. To assess the risks to human and environmental health, the potential impacts of contaminant exposure on identified receptors must be determined.

Objectives

Burrowing and excavation of the soil by small mammals, including deer mice, has been shown to be responsible for some radionuclide transport through the SDA environment; however, the genomic effects of exposure to contaminants at the INEEL was not known. Research was needed to develop new techniques to determine the effects of that exposure to the genome of individuals, so that environmental and remedial actions can be properly implemented. The objectives of this research were to:

- Perform comparative analysis of mother/offspring genotypes across the study areas using allelic data compiled from two consecutive field seasons (14 genetic markers: 147 females; 529 embryos; and 9464 Polymerase Chain Reactions).
- Identify mutant alleles in all samples and perform statistical analysis.
- Perform microsatellite genetic analysis of the four study area populations to determine population structure using a variety of genetic software packages.
- Analyze radiological data obtained from all the females collected during fiscal years 2001 and 2002 and perform statistical analysis.

Accomplishments through 2003

Laboratory Experimental Procedures - Fourteen genetic markers were used to perform microsatellite genetic analysis. Data were organized by population and families; allelic maternal segregation of the offspring was determined, paternal alleles inferred, and mutations identified. Only mutations of alleles segregated from the mother were used for this analysis. Not all the families provided useful data and some had to be removed for the genetic analysis (36 percent of the families were removed).

Mutation Rate Analysis Results - The ratio of microsatellite mutant alleles versus the non-mutant alleles was used as a direct assessment of mutation using parent/offspring comparison of allele differences. Allele scoring was performed with 14 microsatellite markers for females and offspring from the four study areas. The proportion of mutant alleles from each population was pair-wise compared between populations and tested for significant differences using the Fisher's exact test. The statistical analysis suggests that there is no significant difference when comparing the two contaminated sites (RWMC and SL-1) with the two control sites (Burn and Atomic City).

Population Genetic Structure Analysis - Four different approaches were used to test for population genetic structure:

- The allele frequency differences among populations were tested using the Fisher's exact test, where an unbiased estimate of the p-value of the probability test is obtained. The null hypothesis (H_o) "the allelic distribution is uniform across populations" was tested for each locus on a contingency table.

- The differences in genotype distribution across the populations were based on estimates of Wright's F-statistics. The null hypothesis, $F_{st} = 0$ "the genotypic distribution is uniform across populations" was tested for all loci using a chi-square goodness-of-fit test.

- The estimate of Rho_{st} statistics is a measure analogous to F_{st} but incorporates allele size estimates and assumes a step-wise mutation model.

- Finally, an assignment test was performed using GeneClass. This test uses a Bayesian approach to detect immigrants by using multilocus genotypes.

The null hypothesis was rejected in the first two methods; that is, the differences in allele frequency distribution and the genotype distribution differences between populations are statistically significant. The third method indicates that some level of gene flow occurs between populations but not enough that the distributions of alleles or genotypes between them are homogenized. The assignment test also supports population genetic structure because 98.61 percent of the individuals were correctly assigned to their population of origin.

Radiological Analysis - Samples from 80 females were used for this analysis: 43 from Atomic City; 21 from SL-1; and 16 from RWMC (the Burn site was excluded from the analysis due to small available sample size). Female carcasses were processed and analyzed for presence of radiological contaminants. None of the females showed exposure at levels higher than background. Statistical analysis of the radiological data indicates that the differences between the populations are not significant. That is, female mice collected from RWMC and SL-1 had similar levels of radiological (background) contamination compared to the Atomic City control site.

Results

The populations have different allelic frequency composition, and even though there is evidence that some level of gene flow occurs, and that they are not isolated completely, the migration rate is not strong enough to create a panmictic population (a population with no genetic structure). This study indicates that the four populations are distinctive when comparing the two control sites with SL-1 and RWMC population.

It is assumed that natural populations share the same level of mutation rate, because this is an evolutionary force that is stochastic. This means that it is not affected by any of the evolutionary selective forces, and it occurs at a very low frequency. If there are no other contributing factors such as anthropogenic activities, it is predicted that in all of the studied populations the mutation rates should be similar. This study shows that there is no difference in the rate of mutation in populations exposed to anthropogenic activities in comparison with populations that have had little or no exposure. This suggests that no external forces (outside from evolutionary forces) are acting on this population.

The population genetic analysis and the mutation rate data support each other. The population genetic analysis suggests that there is a geographical component that plays a role in population differentiation. The radiological analysis indicated that the animals collected at the RWMC site have the same level of background exposure as the ones from the other three sites. Based on this study, we cannot conclude that exposure to radiological contaminants is an issue of concern for mice collected at RWMC or SL-1. One observation that is important to make, however, is that samples were not allowed to be collected from areas of known soil contamination. Therefore, the question of whether microsatellites are a good tool for identifying mutation differences caused by exposure still needs to be tested.

Further research should be pursued using this species as a biological indicator for environmental monitoring of contaminants, as well as long-term stewardship and ecotoxicological studies.

This research is part of a long-term plan for building a capability at INEEL in the use of genetic markers to address environmental issues. Once the technology is established, numerous applications using other species as environmental monitoring indicators can be explored. This information will help researchers focus resources and efforts on environmental monitoring at sites where there is a high probability of adverse biological impact caused by the presence of contaminants.

9.6 Crested Wheatgrass (*Agropyron cristatum*) Rates of Spread into Native Sagebrush Steppe in Eastern Idaho

Investigators and Affiliations

Valerie Sheedy, Graduate Student, Idaho State University Department of Geosciences, Pocatello, ID

Keith T. Weber, GIS Director, Idaho State University-GIS Training and Research Center, Pocatello, ID

Nancy F. Glenn, Assistant Research Professor, Department of Geosciences, Idaho State University, Boise, ID

Roger D. Blew, Ecologist, Environmental Surveillance, Education and Research Program, S.M. Stoller Corporation, Idaho Falls, ID

Michael Jackson, Idaho National Engineering and Environmental Laboratory, Idaho Falls, ID

Funding Sources

INEEL Student Outreach and Education in Remote Sensing from Bechtel BWXT Idaho, LLC

Idaho State University Office of Research and the GIS Center

Background

Loss of sagebrush steppe rangeland has had a large impact on sagebrush obligate wildlife. A number of factors have been associated with the decline in sagebrush steppe including conversion to cropland, urban development, invasive species and conversion to other vegetation community types. Following a 2002 fire on the INEEL, conversion of a rangeland with a sagebrush canopy to a crested wheatgrass dominated grassland was observed. Land cover change of this sort could have important impacts for management of sagebrush-obligate wildlife. This prompted questions about the ecology of crested wheatgrass in the upper Snake Rive Plain and the potential risks to remaining sagebrush steppe caused by the spread of crested wheatgrass. First among those questions were:

- Can crested wheatgrass in range improvement and other plantings invade into nearby, good condition sagebrush steppe?
- If so, how fast does it spread?

Objectives

The objectives of this study were to assess the spread of crested wheatgrass from plantings into sagebrush steppe in the upper Snake River Plain. Specific goals included:

- Developing a GIS layer of historic crested wheatgrass plantings on the INEEL.
- Mapping the present extent of certain crested wheatgrass communities.
- Estimating the rate of spread into adjacent good condition sagebrush steppe.

Accomplishments through 2003

During 2003, two sites were selected for study. One site was along Lincoln Boulevard and one at Tractor Flats. The Lincoln Boulevard crested wheatgrass planting was conducted to revegetate roadside and ditches for this paved roadway. The road was originally built in 1952, but was gravel and not paved. The road was upgraded in the early 1970s (exact date is uncertain) and again in 1991. Aerial photographs from 1976 showed that the road had been paved and that the vegetation immediately adjacent to the roadside (primarily the ditches) was different from that further away from the road. Archival photographs of this section of road in 1981 clearly show that this different vegetation is crested wheatgrass. This suggests that crested wheatgrass was planted sometime before 1976. The roadsides were again planted with crested wheatgrass after road upgrades in 1991. The native vegetation type in this area is primarily Wyoming big sagebrush steppe. This area has not been grazed by livestock since the 1940s.

Tractor Flats was planted to crested wheatgrass in 1955 to revegetate an area infested with halogeton *(Halogeton glomeratus)*. This crested wheatgrass community was mapped in 1965 from aerial photographs as part of a vegetation community mapping project. Native vegetation of the area is Wyoming big sagebrush steppe. This area is part of the U.S. Bureau of Land Management (BLM) Twin Buttes Allotment and is grazed by sheep in spring.

The boundaries of the crested wheatgrass invasion were mapped with global positioning system (GPS) receivers. Receivers used were Trimble ProXL and GeoIII. The GPS receivers collected data at a rate of one point every three seconds. All the data was differentially (± 1-5 m [± 3.3-16.4 ft]) corrected using Pathfinder Office. The corrected files were then exported to Arc shapefiles, converted into coverages, and edited to fix overlapping boundaries. Different approaches for mapping the extent of spread of crested wheatgrass were used at each of the two study locations, Lincoln Boulevard and Tractor Flats.

At the Lincoln Boulevard site, a GIS coverage of the extent of spread was created by walking with a GPS as described above on a path following the furthest crested wheatgrass plants from Lincoln Boulevard. This was done on both the east and west sides of the road. To calculate how far the crested wheatgrass had spread, a line was digitized over Lincoln Boulevard on an existing GIS coverage for roads. Then, the crested wheatgrass boundary coverage was converted to points using ARCPOINT and the NEAR command was used to measure the distance from each of those points to the Lincoln Boulevard line.

At the Tractor Flats site, a GIS coverage of the extent of spread of crested wheatgrass was created by using GPS to map the extent of spread in areas near existing roads and at some remote areas. In four areas, sections of the boundary were mapped. Using the GPS data and a SPOT 10 m (32.8 ft) image as a guide, ArcEdit was used to create a polygon to estimate the total area now inhabited by crested wheatgrass. NODESNAP was used at 20 m (65.6 ft) to add lines to connect the GPS measurements. GENERALIZE was then used to smooth out the GPS lines as they had small loops and a very irregular texture. The Tractor Flat polygon created for estimating the spread of crested wheatgrass is an estimate based on the actual boundary lines mapped.

Results

At the Lincoln Boulevard site, the mean distance from the road centerline to the farthest crested wheatgrass individual was 447.0 m (1467 ft) with a maximum distance of 818.6 m (2686 ft). On average, more than 50 percent of the crested wheatgrass points have spread 300 to 500 m (984 to 1640 ft) from Lincoln Boulevard. The distribution varies from one side of the road to the other. On the west side, more than 70 percent of the points are in the 300 to 500 m (984 to 1640 ft) range. The majority of points on the east fall between 400 and 600 m (1312 to 1969 ft) from Lincoln Boulevard with approximately 13 percent in the 600 to 700 m (1969 to 2297 ft) range. On the east, more of the points have spread farther from Lincoln Boulevard. If the roadside was first planted with crested wheatgrass in 1976, based on aerial photos taken that clearly illustrated the presence of a vegetation boundary on either side of the road, the rate of spread was 16.5 m/yr (54 ft/yr).

At Tractor Flats, crested wheatgrass increased its coverage from 692.5 ha (1710.0 acres) in 1965 to 1708.7 ha (4222.3 acres) in 2003. This translates to a spreading rate of 26.7 ha/yr (66.0 acres/yr) or about 18.7 m/yr (61 ft/yr).

On the upper Snake River Plain, crested wheatgrass does invade beyond the area planted into otherwise good condition sagebrush steppe. Rate of spread by crested wheatgrass in an area spring-grazed by sheep was similar to that in an area not grazed by livestock.

9.7 Experimental Remote Sensing of Vegetation on the INEEL

Investigators and Affiliations

Nancy F. Glenn, Assistant Research Professor, Department of Geosciences, Idaho State University, Boise, ID

David R. Streutker, Postdoctoral Researcher, Department of Geosciences, Idaho State University, Boise, ID

Jacob T. Mundt, Research Associate, Department of Geosciences, Idaho State University, Boise, ID

Funding Sources

ISU-INEEL - Partnership for Integrated Environmental Analysis Education Outreach Program

NASA

Background

This study encompasses several areas within the Birch Creek watershed of the INEEL. The Birch Creek watershed is an ecologically sensitive area and includes a portion of a national sagebrush steppe reserve which is pristine habitat for a number of native species. Precise inventories of ecologic biodiversity in this region assist in the assessment of natural diversity and ecological indicators. This study uses both passive and active remote sensing technologies to assess conservation targets on the INEEL. Specifically, the objectives of this study are to develop the use of hyperspectral remote sensing to monitor spotted knapweed (*Centaurea maculosa*, an invasive species), and airborne laser swath mapping (ALSM) to determine low-height vegetation canopy structure.

Although the application of hyperspectral remote sensing to vegetative mapping is relatively new, recent publications have demonstrated a degree of confidence in the ability of this technology to accurately model a landscape. This study uses HyMap hyperspectral data

(HyVista, Inc.), which records incident solar radiation naturally reflected from the surface target (e.g. passive remote sensing) using an airborne sensor. The high spatial and spectral resolution of this imagery differentiates electromagnetic absorption features that are commonly associated with vegetative targets. Spectral component analysis of these datasets allows for a detailed composition of the ecosystem to be assessed, thereby enabling a large area to be mapped in detail in a relatively short amount of time.

Airborne laser swath mapping (ALSM) is a relatively new and quickly growing field of active remote sensing which makes use of a scanning pulsed laser mounted aboard an airborne or satellite platform. Highly accurate timing instruments measure the pulse travel time, and when used in combination with a GPS and an inertia measurement unit (IMU), are able to determine the elevation of the surface from which the laser pulse is reflected. The ALSM data used in this study (Airborne 1) has a vertical accuracy of less than 10 cm (4 in.) and a horizontal accuracy of less than 1 m (3.2 ft).

Of the numerous studies of canopy structures using ALSM, the vast majority have targeted forests. This is due in part because many ALSM sensors have a vertical accuracy on the order of tens of centimeters and, as such, are well suited to canopies many meters high. In the case of some rangeland areas, however, the canopy heights (i.e. for grasslands) are of the same order as or slightly greater than the sensor accuracy, making it difficult to extract significant information about the vegetation. This study attempts to quantify the sensitivity limits and ultimately the usefulness of ALSM vegetation mapping within a rangeland setting.

Five ALSM areas and four hyperspectral lines were acquired in summer 2002 on the INEEL (Figure 9-7). The ALSM datasets range in size from 2 to 15 km^2 (0.8 to 5.8 mi^2) and have post densities of approximately 1.2 m^{-2} (13 ft^{-2}). Each ALSM data point measurement records time, X and Y coordinates, elevation, and intensity values for the both the first and last return of the laser pulse. The hyperspectral data sets are approximately 2 by 20 km (1.2 to 12.4 mi) each, with a 3.5 m (11.5 ft) spatial resolution and 126 spectral bands in the visible and infrared portions of the electromagnetic spectrum (wavelengths ranging from 450 nm to 2.48 µm).

Objectives

Hyperspectral Data Analysis - Using the hyperspectral data, the primary objective is to produce a remote sensing-based classified map of spotted knapweed in the Birch Creek watershed. The classified map is validated with field ground truth data. Additionally, this study aims to assess the spectral separability of the sagebrush with grasses (e.g. crested wheatgrass, fescue, and/or bunchgrass) in the study area. This project includes:

- Assessing and rectifying the geometric precision of the hyperspectral data;
- Validating and refining classifications for distribution of spotted knapweed in Birch Creek using field data; and
- Exploring the potential to differentiate vegetative species from background (e.g. soil) in a semi-arid climate

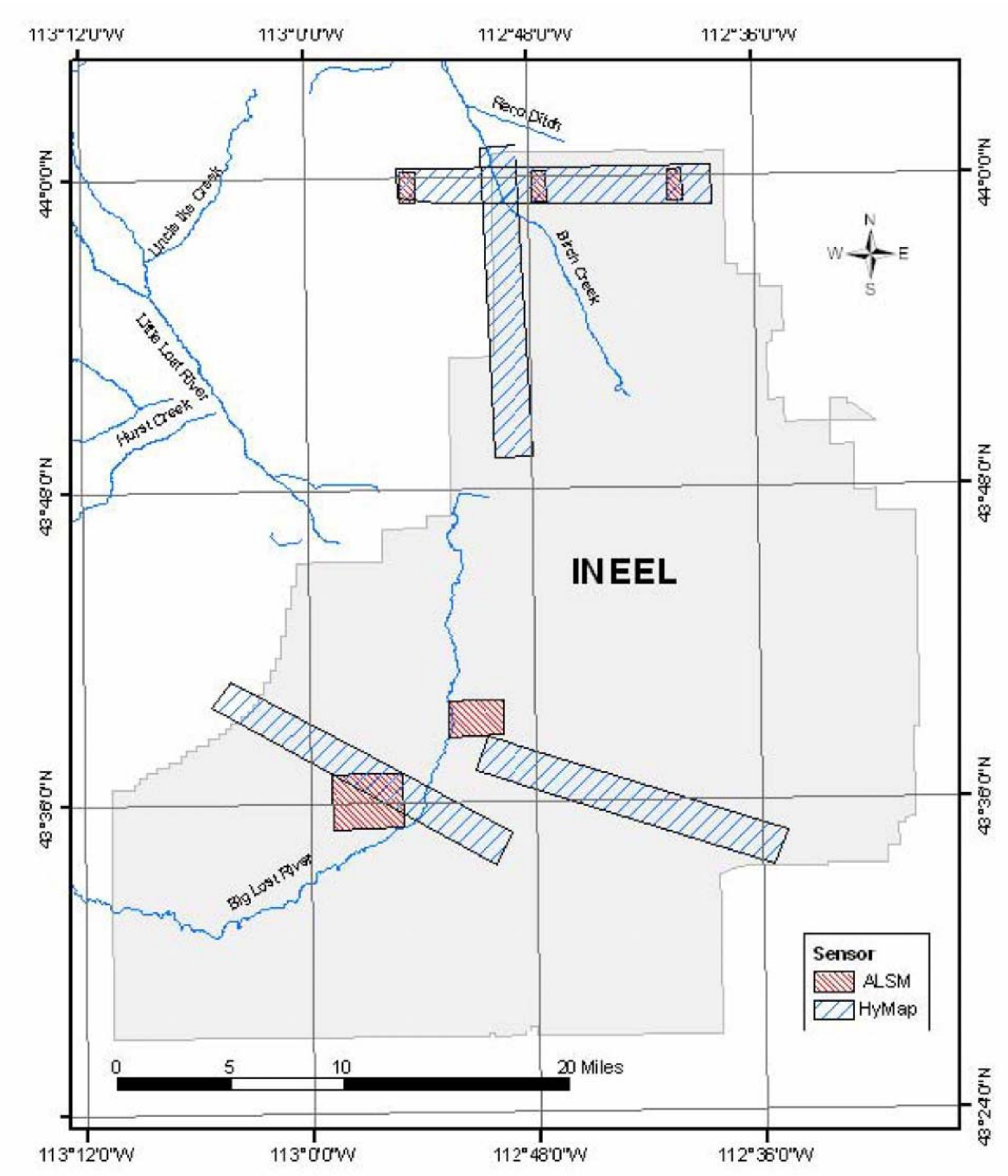

Figure 9-7. Locations of data acquisitions on the INEEL. (The area inside the green outline corresponds to the area illustrated in Figure 9-8.)

ALSM Data Analysis - Using the ALSM data, the primary objective is to determine the heights of various types of rangeland vegetation to an accuracy of a few centimeters. This allows for the discrimination between rangeland grasses (both native and nonnative) from sagebrush, bitterbrush, and other types of low-lying vegetation. Such information is of value in monitoring the recovery of burned sagebrush stands as well as determining where invasive grasses (i.e. cheatgrass) are replacing native stands of sagebrush.

The project scope includes:

- Georeferencing the ALSM data to an accuracy of better than 0.5 m (1.6 ft);
- Validating the calculated ground surface models;
- Determining ALSM reflection/penetration rates into the rangeland canopy and relating such measurements to canopy cross-sections, surface area, and/or biomass;
- Validating discrete vegetation height data points;
- Validating surface roughness characteristics over various length scales; and
- Correlating vegetation height and surface roughness to recovery characteristics in recently burned areas.

An additional objective of this study, to be investigated during summer 2004, is to fuse the ALSM data with hyperspectral data. In areas where the sensors' data overlap, each dataset will be classified independently to map the distribution of both brush and grass groundcover types. Following co-registration, comparative analysis of these datasets in combination with field validation will be performed. For example, the study will address whether the ALSM data is applicable solely to mapping structure (e.g. vegetation heights) or whether it can also provide species discrimination (based on vegetation canopy structure) comparable to the hyperspectral data. The study will also compare the cost and processing feasibility of each dataset.

Accomplishments through 2003

The hyperspectral classification data analysis has been completed for the distribution of spotted knapweed on INEEL (Figure 9-8). Field validation for the classification is ongoing (summer 2004). Several theoretical issues have been explored during data analysis, including hyperspectral processing methods, geometric precision, GPS data integration, field spectra modeling and training, and atmospheric influences. More information on these techniques may be found in Mundt (2003).

Computational algorithms have been developed to analyze the ALSM data for the INEEL. These algorithms use an iterative method to separate the ALSM data into bare ground and vegetation categories. This allows the underlying ground surface to be modeled and subsequently subtracted from the vegetation data, resulting in the vegetation heights. The length scales on which these algorithms operate are determined by a surface fractal analysis.

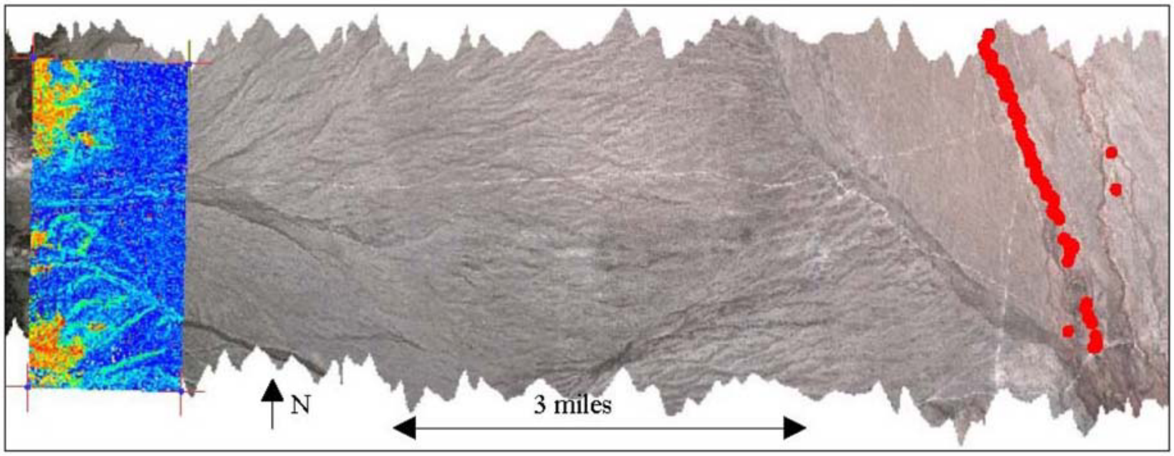

Figure 9-8. Preliminary predicted distribution of spotted knapweed (red points on the right) and modeled surface roughness (superimposed image on the left) generated using the hyperspectral and ALSM data, respectively. (Surface roughness increases from blue to red.)

In the interest of preserving the accuracy of the ALSM data, the raw, irregularly spaced data points are used in the analysis in lieu of interpolating the data into a regularly spaced digital elevation model (DEM). Because the datasets are quite large (several millions of data points), much effort has been invested in developing computationally efficient and numerically precise algorithms. These efforts were presented in a poster titled "Detection and characterization of rangeland vegetation using airborne laser swath mapping" at the Fall 2003 meeting of the American Geophysical Union (Streutker 2003).

Results

Hyperspectral Data Analysis - At this time, field data indicates a high accuracy potential, with approximately 80 percent of classified pixels falling within known spotted knapweed occurrences in the remote sensing-derived map. While these numbers are preliminary and additional field data needs to be collected, the initial results are encouraging for the differentiation of relatively sparse vegetation in a semi-arid ecosystem.

ALSM Data Analysis - Initial maps of vegetation height have been produced for the areas under investigation in the INEEL, as well the other areas in eastern Idaho for which data was collected (e.g. U.S. Sheep Experiment Station, Dubois). The calculated vegetation heights range from a few centimeters for grasslands, several tens of centimeters for sagebrush, and several meters for trees. In areas of recent fires, the fire boundaries are clearly delineated within the vegetation height data. The vegetation height data is also used to calculate surface roughness, which can, in turn, be utilized in discriminating between different vegetation communities (i.e. dense sagebrush stands versus grasslands).

Plans for Continuation

Concurrent with the validation of the spotted knapweed study and validation of the vegetation heights in the ALSM-derived maps, field data will be collected to map the biodiversity where the ALSM and hyperspectral data overlay. This will include detailed GPS measurements of vegetation distribution and structure.

9.8 Natural and Assisted Recovery of Sagebrush *(Artemisia Tridentata)* in Idaho's Big Desert: Effects of Seeding Treatments and Livestock Grazing on Successional Trajectories of Sagebrush Communities

Investigators and Affiliations

Mike Pellant, Idaho State Office of the Bureau of Land Management, Boise, ID

Roger D. Blew, Amy D. Forman, and Jackie Hafla, Environmental Surveillance, Education and Research Program, S.M. Stoller Corporation, Idaho Falls, ID

Robert Jones, U.S. Department of Energy Idaho Operations Office, Idaho Falls, ID

Greg White, Idaho National Engineering and Environmental Laboratory, Bechtel BWXT Idaho, LLC, Idaho Falls, ID

Trish Klahr, Alan Sands, and Robert Unnasch, The Nature Conservancy, Boise, ID

Funding Sources

U.S. Bureau of Land Management

U.S. Department of Energy Idaho Operations Office

The Nature Conservancy

Background

Averaged over the last 10 years, approximately 95,000 ha (235,000 acres) of lands managed by the BLM in Idaho have burned annually. The BLM and other managers of Idaho rangelands, including the INEEL, must decide whether the burned areas need stabilization and rehabilitation treatments to prevent soil erosion and inhibit the invasion of exotic species such as cheatgrass *(Bromus tectorum)*. Most of these rangelands have historically been dominated by big sagebrush *(Artemisia tridentata)*, which does not resprout after fire. Sagebrush provides critical food and habitat for sage grouse, a species proposed for listing under the *Endangered Species Act*. With the accelerating loss of native sagebrush communities and habitat for sage grouse and other sagebrush-obligate species, sagebrush reseeding following fire has become an important consideration, as has the issue of livestock grazing impacts on recovering native vegetation and seeded areas. In the last three years, approximately 70 percent of the sage grouse habitat in eastern Idaho's Big Desert has been burned by wildfire. Fire suppression and rehabilitation costs are rising, and the threats to human life and property are increasing in eastern Idaho.

This study has been divided into three components to address management concerns relative to: (1) native plant recovery in good ecological condition rangeland, (2) success of aerial seeding sagebrush, and (3) whether livestock grazing affects recovery on sagebrush steppe rangelands. These three components will provide new scientific information that addresses current management concerns relative to wildfire impacts and rehabilitation treatments on the eastern Snake River Plain. These studies are designed to establish long-term, replicated monitoring sites that can be reread in the future to provide additional information to managers about post-fire recovery and rehabilitation success. These studies will also provide insight into restoring sagebrush and understory herbaceous species for sage grouse and other sagebrush obligate wildlife species and domestic livestock in the Great Basin.

Objectives

The overall objectives of this research project are to examine some of the key factors that influence trajectories of community diversity and structure following wildfire in sagebrush-steppe ecosystems. Specifically, the factors that influence the recovery of these systems following fire and the replacement of native plant communities with vegetation dominated by cheatgrass *(B. tectorum)* will be examined. The three basic research objectives were to:

- Describe post-wildfire trajectories in community composition and structure in areas in good ecological condition;
- Compare sagebrush recruitment on areas that have been aerially seeded to areas relying on natural recruitment processes; and
- Determine whether trajectories of community composition and structure differ between areas returned to grazing after fire and areas where grazing is excluded.

Accomplishments through 2003

To address the second objective, surveys for sagebrush seedlings were conducted along transects 1000 m (3281 ft) in length. Surveys were conducted May 7 to 9, 2003. A total of 24 transects were surveyed. There were six transects in each of four planting treatments. In the 2000 Tin Cup burn area, there were six transects in the area aerially seeded with sagebrush in 2001, and six transects in an area of the same burn that was not planted. In 2003, two additional sets of transects in the 1994 Butte City Fire area were added. A portion of this burn was planted in 2001 at the same time the 2000 Tin Cup Fire area was planted. Six transects were established in the planted section of this burned area and six were established in the unplanted area. This was done to determine if the six years of recovery of native vegetation prior to planting sagebrush would have an effect on the establishment of sagebrush.

To address the first and third objectives, paired research plots were established in a portion of the area burned by the 2000 Tin Cup Fire. Grazing exclosure fences were constructed around one plot from each pair. The exclosed plot will be used to address questions related to recovery of vegetation in ungrazed sagebrush steppe rangeland. The unfenced plot will be used to examine the role of livestock grazing on that recovery. In all of these plots, plant cover, species richness and diversity were measured. Permanent photoplots and photopoints were established and photographed.

To address the first objective further, plots for addressing plant density and species richness in some of the older burned areas on the INEEL were established.

Grazing treatments were initiated in 2003 so utilization measurements were made. Utilization was measured with the Ocular Estimate Method. Key species (one grass and one forb) were selected for each plot. Selection criteria included consideration of the most abundant species that had actually been grazed and for which there were sufficient numbers of individuals in the plot to obtain a reasonable sample.

Results

In the area burned in 2000, very few sagebrush seedlings were found in 2003. The few that were located during the survey were mostly found in cracks in lava outcrops. In the area burned in 1994, results were opposite of what was expected. The hypothesis was that aerial seeding may be more successful because it was more likely that the seed would not have been as easily blown off of the project areas as appeared to be the case in the 2000 burn. This was expected because the 1994 burn had substantial grass and forb recovery by the time the seed was applied and would have increased boundary layer effect reducing the tendency of the seed to be moved by wind. Wind erosion of soils had stopped before seeding on the 1994 but much erosion was noted on the 2000 burn during the months following seeding. Instead, it was found that in the area burned in 1994 the unplanted area had nearly twice as many seedlings as the planted area.

Species Richness, Density, and Frequency - A total of 70 plant species were encountered in the ten pairs of plots (20 plots). Twelve species found in 2002 were not found in 2003 and four new species were added in 2003. Most of those lost were native annual forbs. Wyoming big sagebrush was encountered in two plots in 2003.

Of the 32 plots planned for study in the older burns, surveys were completed on 18 during 2003. The remainder will be surveyed in 2004. A total of 86 species were encountered on the 18 plots.

Coefficient of community is percentage of total species that the two communities have in common. It was calculated to compare the two plots of each pair for similarity in terms of the species present. Coefficient of community varied from 0.60 to 0.81. On average, the coefficient of community went down slightly from last year, perhaps reflecting the effects of grazing.

Utilization - Utilization of grasses ranged from 3.3 to 11.7 percent with an average utilization of 9.2 percent. Forb utilization was generally lower with a range of 0.9 to 21.7 percent with an average utilization of 5.3 percent.

Plant Cover - Total plant cover on the paired plots was 12.9 percent. Shrub and grass cover were 6.7 and 2.3 percent, respectively. Perennial forb (wildflower) cover was 3.5 percent. Cover by introduced species (weeds) was 0.4 percent.

Plans for Continuation

In 2004, there are plans to continue similar data collection for diversity, richness and cover in the paired plots; the sagebrush seedling survey; and diversity and richness in the older burns.

9.9 Sagebrush Demography on the INEEL

Investigators and Affiliations

Amy D. Forman, Plant Ecologist, Environmental Surveillance, Education and Research Program, S.M. Stoller Corporation, Idaho Falls, ID

Roger D. Blew, Ecologist, Environmental Surveillance, Education and Research Program, S.M. Stoller Corporation, Idaho Falls, ID

Funding Sources

U.S. Department of Energy Idaho Operations Office

Background

As more and more sagebrush steppe habitat in good ecological condition is lost, it becomes increasingly important to understand the ecosystem dynamics of that vegetation type, especially the biology of the dominant species, sagebrush. An understanding of the population dynamics, or demography, of sagebrush should allow land managers to make better decisions about remaining healthy sagebrush steppe vegetation. An understanding of what the historical population dynamics of a sagebrush stand may have been like will also allow land managers to begin to understand how to make improvements in sagebrush steppe communities that are in somewhat degraded conditions.

At the INEEL, the DOE is responsible for the stewardship of 2300 km^2 (890 mi^2) of relatively pristine sagebrush steppe habitat. This land comprises one of the largest reserves of this type of ecosystem that has been largely exempt from anthropogenic disturbance. Some of the primary issues DOE must address as a land manager include fire risk and fuel management, post-fire vegetation recovery, rangeland health, wildlife habitat management (including habitat critical to the survival of threatened, endangered, and sensitive species), and land use planning. Sagebrush is an important component of managing for all of these issues. Unfortunately, the population biology of sagebrush is not well understood. In particular, very little information is available on the typical age structure of sagebrush stands, the frequency of recruitment events, the dynamics of shrub die-off, and the typical lifespan of sagebrush.

The overarching goal of this proposed study is to describe sagebrush stand age structure for a representative sample of sagebrush stands and to identify the population dynamics that influence

that structure at the INEEL. Characterizing sagebrush stand age structure is a critical component to managing sagebrush steppe ecosystems, and understanding some of the basic biology of sagebrush can add tremendously to DOE's ability to make knowledgeable land management and land use decisions. A simple study to establish a working knowledge of the age dynamics of sagebrush stands can yield information useful to those land management issues listed above. Many of the results from this study may also be applied to sagebrush stands with similar climatic conditions and disturbance regimes range-wide, allowing range managers throughout the West to use the data.

The specific goals of this study are designed to allow some basic conclusions to be made about the demography of sagebrush in mature stands. The working knowledge of the dynamics of stand age structure gained from this study will allow managers to better address all of the land management issues mentioned above. The specific goals for this project are:

- To determine the typical stand age structure or range of stand age structures for mature sagebrush stands.
- To investigate how stand age structure relates to stand condition and shrub die-off for sagebrush.
- To examine the dynamics of sagebrush stand replacement in the absence of wildland fire.

By addressing these goals, the proposed study will facilitate a comprehensive understanding of sagebrush population biology on the INEEL and on climactically similar rangelands including the normal age structure of sagebrush stands, the typical range of variation of sagebrush stand age structure, how age structure of a sagebrush stand relates to stand condition, the dynamics of shrub die-off, the typical lifespan of sagebrush, and the frequency of recruitment events.

Objectives

There are two major objectives for the proposed study. The first is to create a literature database and reprint collection regarding sagebrush demography and related sagebrush topics. The second objective is to conduct a field investigation of sagebrush demography at the INEEL. Products resulting from the completion of these combined objectives will provide researchers with an invaluable resource for information on basic sagebrush biology, which enhances any sagebrush related research. The literature database, reprint collection, technical report, and peer reviewed article resulting from this study will also provide tools that land managers can use to make informed sagebrush management decisions.

Accomplishments through 2003

The literature database was completed as an Endnote library. Endnote is a user-friendly database program specifically designed for literature collections; it is keyword searchable and inserts selected records directly into documents created with word processing software to facilitate compilation of literature cited sections. The reprint collection was completed and is housed with the ESER program.

A comprehensive study proposal was completed and submitted for the field investigation of sagebrush demography at the INEEL. The proposal included a thorough discussion of the literature review, precise goals and objectives for the study, a detailed data sampling and data analysis plan, and deliverables with specific land management benefits for the INEEL.

Plans for Continuation

Commencement of the field study will be dependent on funding in fiscal year 2005.

9.10 Development of an Integrated Watershed Information Management Tool for Long-Term Facilities Stewardship at the INEEL

Investigators and Affiliations

Ron Rope, Advisory Engineer, Ecological and Cultural Resources Department, Idaho National Engineering and Environmental Laboratory, Idaho Falls, ID

Jerry Sehlke, Advisory Engineer, Ecological and Cultural Resources Department, Idaho National Engineering and Environmental Laboratory, Idaho Falls, ID

Dr. David Stevens, Utah State University, Logan, UT

Dr. Dan Ames, Utah State University, Logan, UT

Funding Sources

Laboratory Directed Research and Development (LDRD)

Background

The objective of this research is to provide DOE with Integrated Watershed Information Management Tools that integrate and leverage water and environmental management information leading to improved long-term stewardship decision making on the INEEL and within the associated watersheds. The tools and methods developed are transferable to other DOE and federal facilities and to address national/global watershed management issues. Key components of the system include data management, access and analysis tools, a Bayesian Decision Network (BDN), System Dynamics Model, and options analysis/decision support capabilities.

Work involved data collection and database development for disparate data sources in the watershed and development of disciplinary data analysis and mathematical modeling tools for the Big Lost River (BLR) and INEEL. These tools were integrated into a Integrated Watershed Information Management Tools (IWIMT). Facility and water resource managers, along with stakeholders can use these tools to help evaluate information, management alternatives, and to communicate decisions to other interested parties.

Objectives

The objective of this project was to develop data access, visualization, and analysis tools to support stakeholder understanding of watershed characteristics that are transferable to other watersheds including:

- Collect and compile data pertinent to watershed management decision making.
- Develop a BDN for the BLR specific to INEEL surface water management issues.
- Develop a Systems Dynamic model for the BLR.
- Make data and software tools available to the general public.

Accomplishments through 2003

- A license agreement for using and distributing the software was completed.
- Software documentation has been completed.
- Other applications for the software were developed and are being pursued.
- The software and examples are available at www.MapWindow.com.

Results

The following data for the BLR and INEEL have been compiled and integrated into the BLR-Data Viewer (DV): Groundwater elevation and quality, SNOTEL (SNOwpack TELemetry), snow course and other meteorological data, wildlife corridors for sensitive and focus species, surface water flow and water quality, soil erosion susceptibility, and a precipitation run-off forecasting model.

A data inventory table for the BLR-DV has been organized and updated. This table provides an example of what data are needed to support the tools and how to document and organize the data. The MapWindow software is used as the primary visualization tool, and GIS engine was re-engineered to be more efficient and stable. Software plug-ins were revised to improve system performance.

A soil erosion risk model was developed for the BLR watershed identifying key areas where soils are most susceptible to erosion causing sediment problems in the streams.

A model identifying key wildlife corridors for sensitive and important vertebrate species has been developed for the BLR watershed. This component of the tool set attempts to address terrestrial ecological sustainability for the identified key species.

The structure of the BLR BDN has been completed. The decision nodes are defined and the conditional probabilities tables have been populated. Some modifications to the INEEL portion of the BDN are still taking place to capture additional questions and decisions associated with operation of the BLR diversion on the INEEL.

The system dynamics (SD) model for surface water flow in the BLR is completed, but not calibrated. This model is used to predict stream flows based on different dam operation scenarios and its output will populate the conditional probability tables in the BDN.

A precipitation runoff forecasting BDN was completed for the upper BLR basin above Howe Ranch gauge. This model utilizes historic snow pack snow water equivalent data, flow data, and northern sea surface water temperatures to provide probabilities of upcoming run-off conditions in acre-feet based on five types of precipitation years, and can provide information regarding the amount of water expected in the coming year with an uncertainty component.

A snow-cover run-off model was completed for the Copper Basin portion of the BLR. It provides an estimate of total water run-off based on snow cover in early spring. It provides an additional prediction tool for supporting management options for the Mackay dam. It increases the accuracy and reduces the uncertainty associated with using SNOTEL data alone.

9.11 Ecological Impacts of Irrigating Native Vegetation with Treated Sewage Wastewater

Investigators

Roger D. Blew, Ecologist, Environmental Surveillance, Education and Research Program, S.M. Stoller Corporation, Idaho Falls, ID

Amy D. Forman, Plant Ecologist, Environmental Surveillance, Education and Research Program, S.M. Stoller Corporation, Idaho Falls, ID

Sue J. Vilord, Wildlife Biologist, Environmental Surveillance, Education and Research Program, S.M. Stoller Corporation, Idaho Falls, ID

Jackie R. Hafla, Natural Resource Scientist, Environmental Surveillance, Education and Research Program, S.M. Stoller Corporation, Idaho Falls, ID

Funding Sources

U.S. Department of Energy Idaho Operations Office

Background

In 1995, the INEEL began disposing of treated sewage wastewater at the Central Facilities Area (CFA) by applying it to the surface of soils and native vegetation using a center pivot irrigation system. Research conducted on this disposal method at the INEEL provides an opportunity to determine the benefits and/or hazards of disposal of wastewater on native vegetation in arid and semi-arid regions. Results will be applicable to a wide range of municipal, industrial, and agricultural wastewater disposal needs. Because permits to dispose of agricultural and industrial wastewater may have restriction on application to prevent deep percolation, this research may refine some of the models used to predict the maximum rate of wastewater application possible without percolation below the rooting zone.

The wastewater land application facility at CFA covers approximately 29.5 ha (73 acres). The permit for operating this system limits the application rate to 63.5 cm (25 in.) of water per year, which must be applied such that no more than 7.6 cm (3 in.) of water leaches through the root zone toward groundwater. The 63.5 cm (25 in.) maximum application rate is more than two and one-half times the average annual precipitation and depending on the timing of application, plants may not be able to deplete this in one growing season to prevent leaching. Most of the precipitation in this cool desert biome occurs in the winter and spring, and soil moisture recharge occurs in the spring with snowmelt and rainfall. Therefore, wastewater application must be timed to avoid spring recharge to minimize deep percolation of wastewater. The wastewater also contains organic carbon, nitrogen, other nutrients, and trace metals that may have impacts on the proper functioning of native soil-plant systems.

Different plant species respond differently to addition of water and nutrient elements, especially if those additions come at times of the year that are normally dry. These differences in response can result in some species being favored and others discouraged. Changes in plant community structure can be expected. For example, in arid and semi-arid regions grasses are known to dominate where precipitation occurs mostly in the summer and shrubs tend to dominate in areas where moisture occurs as snow. Summer irrigation may lead to decreases in shrub dominance and increases in grasses.

Changes in plant community structure also mean changing habitats for other organisms such as small mammals, birds, insects, and big game animals. Because the area is relatively small, it is unlikely that decreased habitat quality would have significant impacts on wildlife populations on the INEEL. Increases in habitat quality, however, could have substantial impacts on wildlife use pattern in and near this small area.

Objectives

The primary objective of the research study was to determine the ecological benefits or hazards of applying wastewater on native vegetation in semiarid regions. Specific objectives were to determine the potential for impacts on rangeland quality, resident wildlife populations, and soil water balance.

Accomplishments through 2003

Plant cover sampling techniques were updated in 2003. Plant cover on each plot has been estimated using five contiguous point frames along a single transect through 2002. In 2003, this sampling effort was increased to four contiguous point frames along five perpendicular transects, for a total of 20 point frames per plot. The increased sampling effort will allow for more accurate vegetation cover estimates with less statistical variability. Plant cover surveys were completed in 39 study plots within the three distinct plant community types (sagebrush steppe, crested wheatgrass, and a transition type) on the application area and in control areas adjacent to the wastewater application area.

Soil moisture data was collected once every two weeks at 20 sites in the wastewater application area and 20 control sites throughout the growing season (beginning mid-March and ending at the end of October). Collection of soil moisture measurements was reduced from weekly in 2002 to once every other week in 2003 because changes in water content were very small on a week-to-week basis, and the most important patterns in soil moisture occurred on monthly and seasonal time scales.

A breeding bird survey was conducted according to U.S. Geological Survey (USGS) guidelines on and around the study site to determine any differences between irrigated and non-irrigated areas in bird usage.

Results

Vegetation - Within the crested wheatgrass vegetation type, nearly all plant cover resulted from crested wheatgrass. Total vegetation cover was significantly higher on irrigated plots than on control plots in 2003 ($p < 0.05$). Thus, additional summer moisture from wastewater application did result in an increase in grass cover in this community type. However, with a Morisita's similarity index of 0.99, plant community composition was very similar between irrigated and control plots. Crested wheatgrass communities at the INEEL tend to occur as monocultures; thus, crested wheatgrass communities are very homogenous and unlikely to exhibit much spatial variation, even when disturbed.

The vegetation type that represents a transitional zone between the crested wheatgrass community and the sagebrush steppe community was more greatly affected by the irrigation treatment than the crested wheatgrass community. Although total cover was similar between irrigated and control transitional communities, grass cover was higher on irrigated plots, and shrub cover was much higher on control plots. The Morisita's index value between irrigated and control plots was 0.88, which indicates some differences in species composition between irrigated and control plant communities within the transition zone in 2003.

Species richness was higher in the sagebrush steppe communities than in either of the other two plant communities. As with the crested wheatgrass and transition communities, grass cover was higher on irrigated plots than on control plots within the sagebrush steppe plant community. Forb cover consisted primarily of native forbs and was also higher on irrigated plots than in control plots. The Morisita's similarity index value (0.94) was higher between irrigated and control plots in the sagebrush steppe community in 2003 than in 2002, and was also higher than between irrigated and control plots within the transition zone. Sagebrush steppe community vegetation is more likely to fluctuate in response to disturbance or changing environmental conditions because sagebrush steppe communities are much more heterogeneous and more likely to vary in space and time.

Animals - On June 13, 2003, breeding bird surveys were conducted on the wastewater application area following USGS, Breeding Bird Survey (BBS) guidelines. A BBS route stop was established on the application area in 1997 and surveys have been conducted yearly since that time. In 2003, Western meadowlark *(Sturnella neglecta)* remained the most abundant species. Other common species included Brewer's sparrow *(Spizella breweri)*, Brewer's blackbird *(Euphagus cyanocelphalus)*, horned lark *(Eremophila alpestris)*, sage sparrow *(Amphispiza belli)*, and sage thrasher *(Oreoscoptes montanus)*. One species, brown-headed cowbird *(Imolothrus ater)*, which has been common in the past, was not observed during the 2003 survey. Two species, lark sparrow *(Chondestes grammacus)* and Say's phoebe *(Sayornis saya)* were observed for the first time on the application area this year, but are not uncommon in surrounding areas. Otherwise, results from the 2003 survey were comparable to previous years and similar to that found on the CFA BBS route.

Soil Moisture - Spring soil moisture wetting fronts in 2003 ranged from 0.2 to 0.6 m (0.7 to 2.0 ft) and did not differ substantially between irrigated and control plots. Subsequent to infiltration, soil moisture decreased steadily throughout the wetted profile through the summer as a result of evapotranspiration. Soils began to approach the lower limit of extraction by July in 2003. The soil moisture profiles do not indicate an increase in soil moisture at 20 cm (approximately 8 in.) or deeper due to wastewater application. If irrigation were to affect soil moisture, we would expect to see either small wetting fronts in the profile throughout the summer (in the case of pulses in application), or we would expect soil moisture in at least some portion of the top of the soil profile to remain elevated (in the case of relatively steady application of water). Neither of these patterns is apparent in the irrigated soil profiles. In fact, those profiles dry down throughout the summer in a manner very similar to that of the control soil profiles. Thus, most of the additional water received by a soil profile through wastewater application is evaporated or transpired before it percolates to a depth of 20 cm (approximately 8 in.) within the soil profile. The soil moisture dynamics described here were similar across all plant communities on the application area. Therefore, the probability of water percolating through the rooting zone and continuing to move downward was essentially the same for the wastewater application area and control locations during the 2003 growing season.

9.12 The Protective Cap/Biobarrier Experiment

Investigators and Affiliations

Amy D. Forman, Plant Ecologist, Environmental Surveillance, Education, and Research Program, S.M. Stoller Corporation, Idaho Falls, ID

Funding Sources

U.S. Department of Energy Idaho Operations Office

Background

Shallow land burial is the most common method for disposing of industrial, municipal, and low-level radioactive waste, but in recent decades it has become apparent that conventional landfill practices are often inadequate to prevent movement of hazardous materials into groundwater or biota (Suter et al. 1993, Daniel and Gross 1995, Bowerman and Redente 1998). Most waste repository problems result from hydrologic processes. When wastes are not adequately isolated, water received as precipitation can move through the landfill cover and into the waste zone (Nyhan et al. 1990, Nativ 1991). Presence of water may cause plant roots to grow into the waste zone and transport toxic materials to aboveground foliage (Arthur 1982, Hakonson et al. 1992, Bowerman and Redente 1998). Likewise, percolation of water through the waste zone may transport contaminants into groundwater (Fisher 1986, Bengtsson et al. 1994).

In semiarid regions, where potential evapotranspiration (ET) greatly exceeds precipitation, it is theoretically possible to preclude water from reaching interred wastes by (1) providing a sufficient cap of soil to store precipitation that falls while plants are dormant and (2) establishing sufficient plant cover to deplete soil moisture during the growing season, thereby emptying the water storage reservoir of the soil.

The Protective Cap/Biobarrier Experiment (PCBE) was established in 1993 at the Experimental Field Station (EFS) to test the efficacy of four protective landfill cap designs. The ultimate goal of the PCBE is to design a low maintenance, cost-effective cap that uses local and readily available materials and natural ecosystem processes to isolate interred wastes from water received as precipitation. Four ET cap designs, planted in two vegetation types, under three precipitation regimes have been monitored for soil moisture dynamics, changes in vegetative cover, and plant rooting depth in this replicated field experiment.

Objectives

From the time it was constructed, the PCBE has had four primary objectives:

- To compare the performance of caps having biobarriers (capillary breaks) with that of soil only caps and that of caps based on U.S. Environmental Protection Agency (EPA) recommendations for *Resource Conservation and Recovery Act* landfill caps;

- To examine the effects of biobarriers as capillary breaks placed at different depths within the soil profile on water percolation, water storage capacity, plant rooting depths, and water extraction patterns;

- To evaluate the performance of caps receiving higher precipitation than expected under either the present climate or that anticipated in the foreseeable future; and

- To compare the performance of a community of native species on ET caps to that of caps vegetated with a monoculture of crested wheatgrass.

Specific tasks for the PCBE in 2003 included maintenance of the study plots, continuation of the irrigation treatments, and collection of soil moisture and plant cover data. The data will be analyzed according to the four major objectives listed above and analyses will focus on long-term cap performance. The PCBE has one of the most complete, long-term data sets for ET caps, which makes it a model system for studying ET cap longevity. Long-term performance issues that will be addressed with the PCBE include changes in plant community composition, species invasion, and changes in soil moisture dynamics as the caps continue to age and the biological communities associated with the caps continue to develop.

Additionally, replacement of the polypipe irrigation system was scheduled for 2003. All polypipe components of the irrigation system except the dripline were to be replaced with galvanized steel in anticipation of reducing time and supply costs associated with irrigation system maintenance. Finally, an article for submission to a peer-reviewed journal was to be drafted in 2003.

Accomplishments through 2003

Two supplemental irrigation treatments were completed on the PCBE in 2003. Fifty millimeters (2 in.) of water was applied to the summer irrigated plots once every other week from the end of June through the beginning of August for a total of 200 mm (8 in.). Two hundred millimeters (8 in.) of water was applied to the fall/spring irrigated plots during a three week period in October. Soil moisture measurements were collected once every two weeks from mid-March through the end of October. Vegetation cover data were collected throughout the month of July and into August.

Soil moisture and vegetation data collected in 2003 were archived. Soil moisture data were compiled and summarized, and soil moisture profiles were completed for each cap, irrigation, and vegetation treatment. Vegetation data were also complied and summarized to yield a percent cover value for each treatment combination.

Replacement of the irrigation system began in August of 2003. The entire polypipe system was removed and all of the galvanized components were installed by the middle of October. Approximately two-thirds of the dripline was replaced by the end of the year. The irrigation system replacement was completed in the spring of 2004.

An article entitled "Design and Performance of Four Evapotranspiration Caps" by A. D. Forman and J. E. Anderson was completed and submitted for publication in September 2003. It includes much of the 1993 through 2000 data previously published in Environmental Surveillance, Education and Research (ESER) reports. The manuscript is in review and will be published in a special edition of the Practice Periodical of Hazardous, Toxic and Radioactive Waste Management by the American Society of Civil Engineers (due to be published in early 2005). The special edition includes several invited papers from INEEL scientists on landfill capping issues.

Results

Initial data analyses from the 2003 soil moisture data indicated that the spring infiltration event was limited, with the resulting wetting front ranging from 20 to 60 cm (approximately 8 to

24 in.) in depth. The wetting front from the summer irrigation treatment ranged from 40 to 80 cm (approximately 16 to 32 in.) on all cap type and vegetation treatment combinations. Under the fall irrigation treatment, the wetting front reached the bottom of all of the soil only caps and many of the shallow and deep biobarrier caps regardless of vegetation type. All of the RCRA caps drained in response to the fall irrigation treatment. The soil at the bottom of many of the fall irrigated caps was at or above field capacity, indicating that many of those caps likely drained.

Over the 10-year study period, the widespread cap failure that occurred in response to the fall irrigation treatment of 2003 marks the first event of this type under normal treatment conditions. Soil moisture data will be closely compared with vegetation cover data to determine possible causes of the cap failure. Continued irrigation and soil moisture measurements will be critical over the next few years to gauge whether cap failure under fall irrigation will continue to be a regular event, or whether the cap failure in 2003 was a random and reversible occurrence.

Plans for Continuation

Soil moisture and plant community composition and cover were still experiencing unexpected changes in 2003, as evidenced by the cap failures in response to the fall irrigation treatment. The PCBE should continue to be monitored at least until cap failure occurs consistently, or until the caps recover and the ecological and soil moisture parameters stabilize and long-term fluctuations can be characterized.

Additional recommended research for the PCBE includes studies pertaining to long-term maintenance issues such as response to fire, invasive plant species, erosion, and the role of soil microbiota in cap function.

9.13 Assessing the Effects of Soil-Forming Processes on Surface Caps

Investigators and Affiliations

Terence McGonigle, Research Assistant Professor, Department of Biological Sciences, Idaho State University, Pocatello, ID

M. Lala Chambers, Staff Scientist, Idaho National Engineering and Environmental Laboratory, Idaho Falls, ID

Gregory White, Consulting Scientist, Idaho National Engineering and Environmental Laboratory, Idaho Falls, ID

Funding Sources

Environmental Systems Research and Analysis (ESRA), Environmental Management

Background

Vegetative surface caps for the disposal of radioactive or hazardous wastes are often constructed of homogenized subsoil material collected from the local area. In arid regions, these

caps rely on ET to prevent water from percolating into the waste. Over time, these materials are subjected to natural soil-forming processes, eventually resulting in the development of strata within the soil material that may ultimately influence cap performance. Organic carbon and available phosphorus play an important role in the structure and function of the soil ecosystem by influencing the growth of plants at the site which, through transpiration, help to prevent precipitation from moving downward through the cap and ultimately reaching the buried wastes.

The PCBE was established at the INEEL EFS in 1993 to examine four different simulated surface cap designs under two different vegetation types and three different moisture regimes. Because these caps have been in place for ten years, they represent an example of accelerated soil forming processes, providing insight into plant-soil interactions within the surface cap.

Objectives

Specific objectives for this study include:

- Compare the vertical distribution of carbon and phosphorus concentrations in soil cores from the PCBE site with those from an undisturbed site with mature soil development.
- Evaluate cation nutrients (potassium, calcium, and magnesium) for a subset of the soil cores.
- Determine cation exchange capacity, base saturation, and soil texture on a subset of cores.

Accomplishments through 2003

Soil cores were collected from the PCBE site and from an undisturbed site located nearby. In each sampling location, soil cores were collected from beneath a sagebrush and a bunchgrass, as well as from an open area adjacent to each plant. Six depth intervals within the top 12.5 cm (5 in.) were evaluated by cutting each core into segments. Organic carbon concentrations were determined according to the tube digestion/heating block method, a modification of the Walkley-Black method. For plant-available soil phosphorus, samples were extracted with a buffered alkaline solution of sodium bicarbonate, and the solution analyzed using an inductively coupled plasma atomic emission spectroscopy (ICP/AES) analyzer. Concentrations of individual cation nutrients and measurements of cation exchange capacity, base saturation, and soil texture were determined using standard soil analytical techniques.

Results

Vertical distribution of carbon and phosphorus at the PCBE site was pronounced; indicating that development of soils on the surface caps is progressing (Figure 9-9). A strong interaction between vegetation, location, and depth was observed for both carbon and phosphorus, which reflects the particularly strong organic enrichment under vegetation. There is also an interaction between irrigation and depth, which indicates surface enrichment following irrigation. Cap design effects are mostly absent. For cation exchange capacity and base saturation data, results differed between the PCBE cores and those collected from the undisturbed site. In particular, the potassium data show increased concentrations in the upper soil layers, decreasing with depth. Significant differences are also apparent between samples collected beneath shrub canopies

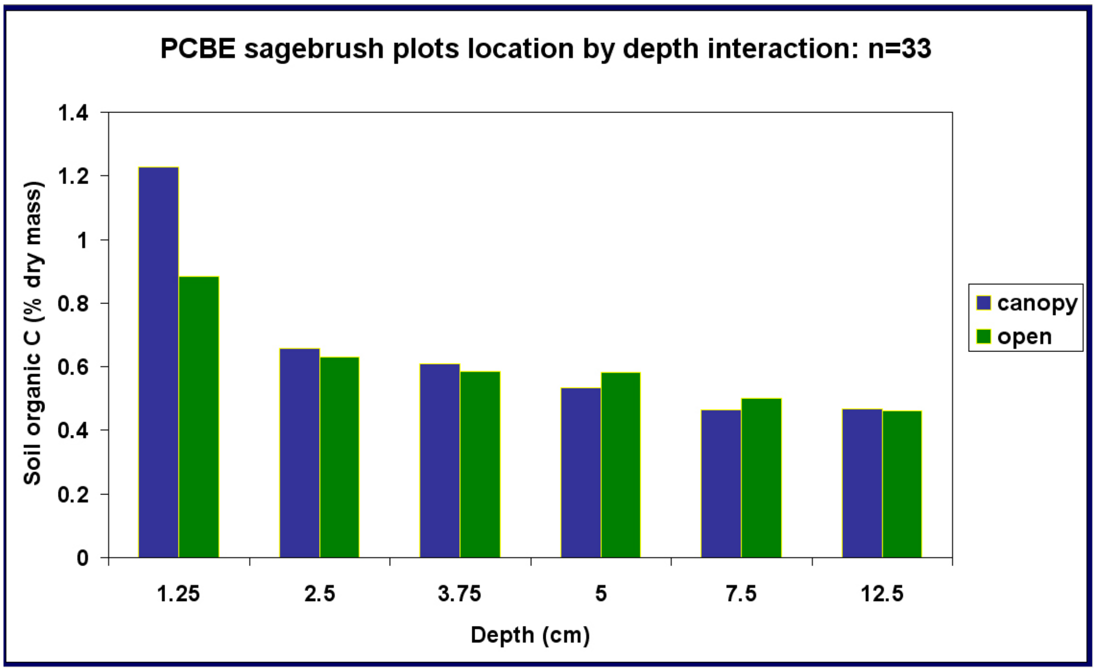

Figure 9-9. Concentration of organic carbon in soil samples at varying depths for samples collected under shrubs (canopy) and between shrubs (open).

versus in the open, again pointing out the influence of vegetation on the chemistry of the cap soil.

Collectively, these data show evidence of discernible development of the upper soil profile in caps after eight years. However, the data also indicate that additional time is needed to approach the accumulation seen in natural soils of sagebrush steppe ecosystems.

The carbon and phosphorus results were presented at the Soil Science Society of America Annual Meeting in Denver in 2003, and a formal journal article has been submitted to the Soil Science Society of America Journal. A second paper on the cation results is in preparation.

9.14 Coupled Effects of Biointrusion and Precipitation on Soil Caps

Investigators and Affiliations

Angela Stormberg, Principal Scientist, Idaho National Engineering and Environmental Laboratory, Idaho Falls, ID

Roelof Versteeg, Senior Advisory Scientist, Idaho National Engineering and Environmental Laboratory, Idaho Falls, ID

Kristine Baker, Principal Scientist, Idaho National Engineering and Environmental Laboratory, Idaho Falls, ID

Carlan McDaniel, Idaho National Engineering and Environmental Laboratory, Idaho Falls, ID

Indrek Porro, Idaho National Engineering and Environmental Laboratory, Idaho Falls, ID

Funding Sources

Environmental Systems Research and Analysis (ESRA), Environmental Management

Background

The National Research Council's characterization of infrastructure material clearly indicates the need to understand, and to be able to predict over the long term, how integrated processes impact the performance of caps used to isolate hazardous or radioactive wastes. It is recognized that biointrusion and the processes it affects comprises a complex network of interactions; however, two pieces of information seem to be missing from previous studies. First, it is not clear what processes and how much time is needed for long-term exposure to biointrusion to actually affect the performance of the cap. Second, to construct more realistic models of cap performance, it is necessary to be able to understand and evaluate cap performance as a function of coupled processes as opposed to single processes.

Engineered barriers are designed to isolate hazardous waste from moving to the environment and ideally, they are expected to sustain functionality well beyond the breakdown of the materials they contain. Current barrier designs are not invulnerable to environmental and biological assaults and, to date, it is difficult to determine the significance of these intrusions on the long-term performance and effectiveness of the barrier. Therefore, it is important to elucidate the interactions between geophysical and biological processes, and how these processes ultimately act on the long-term performance of caps.

Objectives

This study evaluated the coupled effects of geophysical, environmental, and biological intrusions and how those factors ultimately affect the performance of the cap. This project identified and evaluated time and cost-effective early warning methods for detecting biointrusion. The tests were conducted at the Engineered Barrier Test Facility (EBTF) near the RWMC on the INEEL. The objectives of this study were:

- Test coupled effects for a natural material system, especially increased rainfall and the effects of animal and plant intrusion.
- Induce animals to create worst-case (deepest) animal intrusion.
- Test colored sand tracers (emplaced as layers) to show depth of animal intrusion.
- Evaluate capillary barrier performance.

Accomplishments through 2003

The experimental setting was designed to test a series of interactive conditions: burrowing, plant evapotranspiration, and water percolation through the barrier. Mockups of an evapotranspiration-storage type soil cap were constructed in 12 test cells at the EBTF (Figure 9-10).

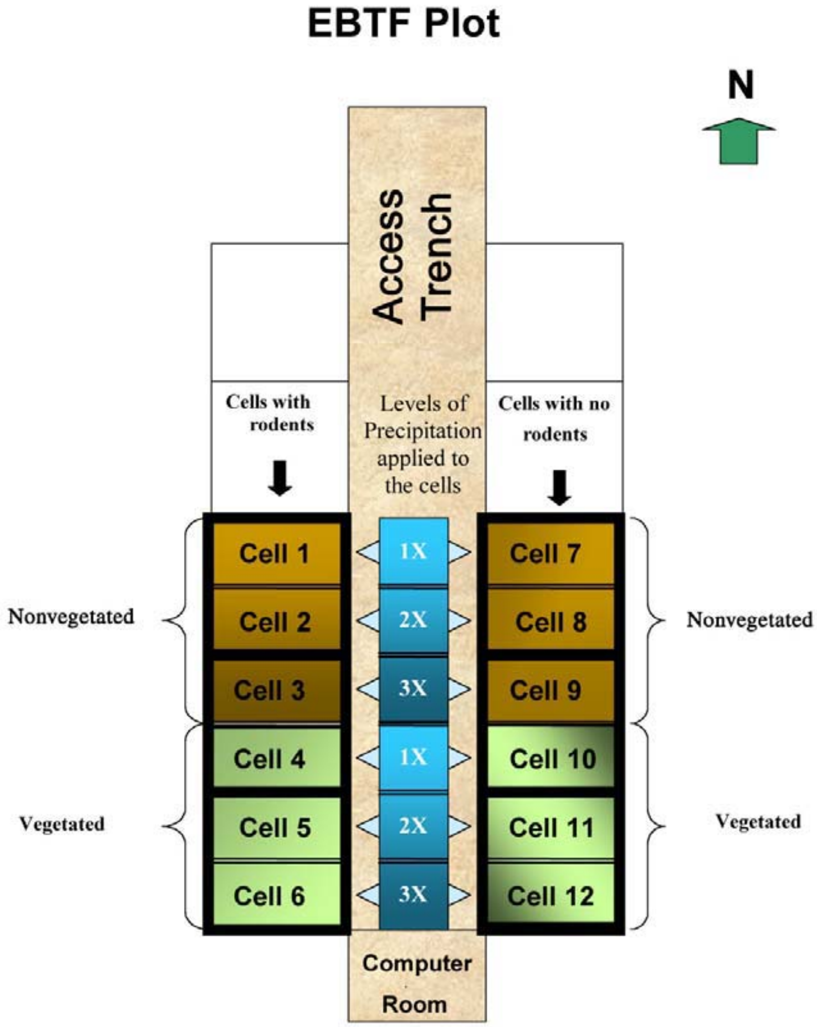

Figure 9-10. Layout of the EBTF plots.

Cells 1 to 3 had rodents (mice) and no vegetation. These cells differ only in the level of precipitation that each cell received (normal, 2X normal, and 3X normal, respectively). Cells 4 to 6 were similar to Cells 1 to 3 with respect to precipitation, the presence of rodents, and the presence of colored sand in the soil. Unlike Cells 1 to 3, however, Cells 4 to 6 were vegetated. The same type and density of vegetation was established on these cells at the start of the experiment. Cells 7 to 9 were similar to Cells 1 to 3 with respect to precipitation and lack of vegetation, but lacked burrowing mammals. Cells 10 to 12 were similar to Cells 4 to 6 with respect to precipitation and vegetation. Again although, Cells 10 to 12 lacked rodents and colored sand in the soil. Cells 1 through 6 had the same number of rodents introduced to each of these cells.

Considered in total, the 12 treatments enabled us to evaluate the coupled effects and interactions between accelerated precipitation, animal burrowing, vegetated/bare surfaces, soil microbiology, and soil cap hydrologic performance.

The caps were comprised of (from top to bottom) 1.6 m (5.2 ft) of silt loam soil, a geotextile fabric, 0.15 m (approximately 5 ft) of gravel, 0.75 m (2.5 ft) of cobbles, and 0.5 m (1.6 ft) of silt loam soil. The surface 0.15 m (approximately 5 ft) of soil was mixed with gravel (25 percent by volume) as a wind erosion preventative.

Each test cap was constructed in lifts to enable precise control of soil density and facilitate the installation of soil moisture monitoring instrumentation and soil tracers for detection of burrowing. Time domain reflectometry (TDR) probes for monitoring soil moisture, heat dissipation sensors (HDS) for monitoring soil moisture tension, and thermocouples (TC) for monitoring soil temperature were installed at various depths. Instrument cables were routed horizontally to a cable tower installed within the test cell. Horizontal installation precluded the creation of vertical preferred pathways for water infiltration at the soil surface. Snowfall accumulating on the test plots was measured using an ultrasonic sensor. Data collection from all soil and snow instruments was automated to provide an uninterrupted time series of data and to reduce manpower requirements. Meteorological parameters were obtained from the National Oceanic and Atmospheric Administration weather station located near the EBTF.

To prevent introduced rodents from escaping and wild fauna from invading the cells (e.g., predators such as snakes or other carnivores, as well as other rodents), 1.5 m (approximately 5 ft) lexan walls were used in the construction of the plots. The walls were buried 20 cm (approximately 8 in.) deep and in direct contact with a concrete lip inside the walls, creating a tight seal and a structural barrier in the event of potential attempts of mice to dig out of the cells. Because the cells were open to the environment (no lids), predation by raptors was prevented using a bird chase ultrasonic model UB43 (Bird-B-Gone, Inc.) that emits a 20 to 25 KHz tone in a variety of mode combinations (i.e.: steady, burst, sweep, and random). This frequency range does not harm the birds and keeps them away from the facility.

Vegetation was incorporated inside plots 4, 5, 6, 10, 11, and 12, following a distribution of vegetation from an area randomly selected in the vicinity of the experimental site. All of the plots were vegetated with the same distribution and type of plants: four sagebrush; four green rabbitbrush; two bluebunch wheatgrass; three prickly phlox, and two forbs. Surveys of test plot vegetation will be conducted at the conclusion of the project to determine the survivorship of plant species and biomass. Test plot soils will be excavated to determine root distributions and biomass. The distribution of animal burrows will be mapped at the conclusion of the project by injecting hardening foam into the burrows and carefully excavating the surrounding soil.

Results

Data collection has just recently been completed and data currently being compiled and interpreted on precipitation, vegetation, and burrowing effects on the cap. Results will be provided in next year's annual report.

REFERENCES

Arthur, W. J. 1982, Radionuclide concentrations in vegetation at a solid radioactive waste disposal area in southeastern Idaho. Journal of Environmental Quality 11:394-399.

Bengtsson, L., Bendz, D., Hogland, W., Rosqvist, H., and Akesson M., 1994, Water balance for landfills of different age, Journal of Hydrology 158:203-217.

Bernardino, F. S. Jr. and Dalrymple G. H., 1992. Seasonal activity and road mortality of the snakes of the Pa-hay-okee wetlands of Everglades National Park, USA, Biological Conservation 61(2): 71-75.

Bowerman, A. G., and Redente, E. F., 1998, Biointrusion of protective barriers at hazardous waste sites, Journal of Environmental Quality 27:625-632.

Daniel, D. E., and Gross, B. A., 1995, Caps. National Technical Information Service, U.S. Department of Commerce, Springfield, Virginia.

Fisher, J. N., 1986, Hydrogeologic factors in the selection of shallow land burial for the disposal of low-level radioactive waste.

Forman, R. T. T. and L. E. Alexander., 1998. Roads and their major ecological effects, Annual Review of Ecology and Systematics, 29:207-231.

Hakonson, T. E., Lane, L. J., and Springer E. P., 1992, Biotic and abiotic processes, in Reith, C. C., and Thomson, B. M., editors, Deserts as dumps? The disposal of hazardous materials in arid ecosystems, University of New Mexico Press, Albuquerque, New Mexico pp 101-146.

Mundt, J., 2003, Detection of Leafy Spurge *(Eurphorbia Esula)* in Swan Valley, Idaho, using Hyperspectral Remote Sensing with Limited Training Data, M.S. Thesis, Department of Geosciences, Idaho State University.

Nativ, R., 1991, Radioactive Waste Isolation in Arid Zones, Journal of Arid Environments 20:129 140.

Nyhan, J. W., Hakonson, T. E., and Drennon B. J., 1990, A water balance study of two landfill cover designs for semiarid regions, Journal of Environmental Quality 19:281-288.

Rosen, P. C. and C. H. Lowe. 1994., Highway mortality of snakes in the Sonoran Desert of southern Arizona, Biological Conservation 68:143-148.

Rudolph, D. C., Burgdorf, S. J., Conner, R. N. and Schaefer R. R., 1999. Preliminary evaluation of the impact of roads and associated vehicular traffic on snake populations in eastern Texas,8 pp In: Evink, G.L., Garrett, P., Zeigler, D., and Berry, J., (eds.) Proceedings of the International Conference on Wildlife Ecology and Transportation.

Streutker, D., 2003, Detection and characterization of rangeland vegetation using airborne laser swath mapping, Fall 2003 Meeting of the American Geophysical Union.

Suter, G. W. I. I., Luxmoore, R. J., and Smith E. D., 1993, Compacted soil barriers at abandoned landfill sites are likely to fail in the long term, Journal of Environmental Quality 22:217-226.